This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

P.. 7

HARVARD UNIVERSITY

LIBRARY OF THE

Department of Mining
and Metallurgy

THE

SCHOOL OF MINES QUARTERLY,

A

JOURNAL OF APPLIED SCIENCE.

VOL. XXIV.

NOVEMBER, 1902, TO JULY, 1903.

COLUMBIA UNIVERSITY,
NEW YORK CITY.

1903.

Per 27

MAY 19 1908
Mining + Met. Laboratory

BOARD OF EDITORS.

A. J. MOSES, Prof. of Mineralogy.
J. F. KEMP, Prof. of Geology.
R. PEELE, Adj. Prof. of Mining.
A. D. F. HAMLIN, Adj. Prof. of Architecture.
R. E. MAYER, Instructor in Drawing.
E. WALLER, Analytical Chemist.
JOS. STRUTHERS, Ph.D.
I. H. WOOLSON, Instructor in Mechanical Engineering.
W. H. FREEDMAN, E.E.
T. H. HARRINGTON, Tutor in Drawing.

Managing Editor R. E. MAYER.
Business Manager, T. H. HARRINGTON.

THE

SCHOOL OF MINES QUARTERLY.

INDEX, VOL. XXIV.

November, 1902, to July, 1903.

All Abstracts are Printed in Italics, and those relating to Chemical Analysis appear only under the heading Analytical Chemistry.

ALUMNI AND UNIVERSITY NEWS.

Chemistry 102
Geology 109
Metallurgy 112
Mining 106

Analytical Chemistry, Abstracts. By Elwyn Waller.

Alkaline Hydrate or Bicarbonate in Presence of Monocarbonate 87
Alumina in Alums 88
Ammonia 510
Antimony in Ores 90
Arsenic and Antimony in Ores 89
" *in Coke* 89
" *in Glycerin* 511
Assay for Gold and Silver in Cyanide Solutions 512
Bismuth in Ores 92
Boric Acid 98, 513
Calculating Water Analysis 86
Copper, Lead, Antimony and Tin in Alloys 93
Cuprous Thiocyanate, Effect of HCl 92
Cyanide-Detection in Presence of Thiocyanate and Ferro and Ferricyanides. 99
Destroying Organic Matter to Apply Tests for Metals, etc. 87
Deterioration of Platinum Crucibles 510
Free Lime in Cements 88
Gold and Silver in Pyrites 91
Gooch and Smith's Method for Chlorates 98
Graphite in Irons 99
Gravimetric for Tellurium 512
Grützner 97
Guttmann 100

Hotsema 100
Hydrochloric Acid free from Arsenic 87
Hydrogen Peroxide 101
KI Test 100
Lead Peroxide in Minium 93
Manganese in Irons 89
" *in Steel* 510
Mercury in Ores 93
Molybdenum, Qualitative 512
" *in Steel* 96
" *Steel* 96
Mondolfo 97
Namias 98
Obtaining Zinc free from Arsenic 87
Ozone Paper 101
Persulphates 97
Platinum in Dental Alloys, etc 90
" *Metals, Detection* 91
Potassium in Kainit 510
Precipitating Thoria 94
Precipitation of Rare Earths 94
Qualitative for Cobalt 89
Reagents in Estimating Arsenic 511
Red Lead 93
Rubrescin, A New Indicator 87
Selenium in Sulphuric Acid 96
Separating Cerium 94
Separation of Arsenic, Antimony and Tin 90
" *of Glucina* 94
" *of Nickel and Cobalt* 89
" " " *Zinc* 89
" (*Qualitative*) *of Arsenic, Antimony and Tin* 511
Silica Determinations 98
Silicon in Aluminum 99
" *in Ferro Silicon* 99
" " *Silicons* 99
Silver in the Residues from Distillation of Zinc 91
Stability Tests for Nitro Explosives, etc 100
Standardizing for Titration of Phosphates 98
Sulphur in Coal 97
" *in Gunpowder* 513
" *in Irons* 97
" *in Pig Iron* 97
" *in Plants* 97
Thomas Test 100
Thorium 94
" *in Monazite Sand* 95
Titanium in Irons, etc 88
Titration of Cyanide and Chloride 99
Tungsten in Ores 95

Uranium Tests. 513
Vanadium Estimation..... 95
" *Titration* 512
Vielle Test..... 100
Volumetric for Selenium..... 96
" *for Zinc*..... 511
" *of Copper* 92
Will Test..... 101
Zinc Titration with Na_2S..... 89
Anisic Acid, Production of, by the Oxidation of Aniseed Oil. By M. T. Bogert and C. H. Zieme..... 500
Antimony, A Study of the Quantitative Determination of. By L. A. Youtz.... 135, 407
Arsenic in Arsenopyrite, A Rapid Method for the Determination of. By J. L. Danziger and W. H. Buckhout..... 400
BARKER, GEORGE F. *Radio-activity and Chemistry* 267
BOGERT, MARSTON TAYLOR, AND ZIEME, C. H. *The Production of Anisic Acid by the Oxidation of Aniseed Oil*..... 500
BOOK REVIEWS:
A Course in Botany and Pharmacognosy. By Henry Kraemer..... 516
Electricity as Applied to Mining. By Arnold Lupton 514
Electro-plating and Electro-refining of Metals. By Arnold Philip..... 117
Hydro-Metallurgy of Copper. By M. Eissler..... 406
Lead Smelting. By Malvern Wells Iles..... 405
Mineral Industry..... 116
Notes on Metallurgical Analysis. By N. W. Lord..... 514
Plattner's Manual of Qualitative and Quantitative Analysis with the Blow-Pipe. Translated by Henry B. Cornwall and John H. Caswell, from the 6th German edition by Professor Friedrich Kolbeck..... 517
BUCKHOUT, W. H., AND DANZIGER, J. L. *A Rapid Method for the Determination of Arsenic in Arsenopyrite*..... 400
Camp Bird Gold Mine and Mills. By H. A. Titcomb..... 56
Cerrillos Hills, New Mexico, The Geology of. By D. W. Johnson.....173, 303, 456
Chemistry and Radio-activity. By G. F. Barker..... 267
Crystallography, New Graphical Methods in. By Austin F. Rogers..... 67
Crystals, Formulæ and Graphic Methods for Determining, in Terms of Coördinate Angles and Miller Indices. By Alfred J. Moses and Austin F. Rogers... 1
DANZIGER, J. L., AND BUCKHOUT, W. H. *A Rapid Method for the Determination of Arsenic in Arsenopyrite*..... 400
Electrochemistry, Practical Laboratory Notes for Students. By S. A. Tucker.... 429
Explosive Mixtures, Some New Work on Properties of. By Charles E. Lucke... 37
FALK, MYRON S. *On the Use of Influence Lines in Graphic Statics*.....119, 350, 440
Formulæ and Graphic Methods for Determining Crystals in Terms of Coördinate Angles and Miller Indices. By J. Moses and A. F. Rogers..... 1
Geology of the Cerrillos Hills, New Mexico. By D. W. Johnson.....173, 303, 456
HALE, F. E. *Upon the Structure of the Starch Molecule*... 145
Iron and Steel at Liquid Air Temperatures, The Magnetic Properties of. By C. C. Trowbridge..... 72
JOHNSON, DOUGLAS WILSON. *The Geology of the Cerrillos Hills, New Mexico.* 173, 303, 456
Laboratory Notes for Students in Practical Electrochemistry. By S. A. Tucker. 429

Latest Progress in Shaft Sinking. By Chief Engineer Riemer..... 361
Lead Veins, The Rossie. By C. H. Smyth, Jr. 421
LUCKE, CHARLES E. *Some New Work on Properties of Explosive Mixtures*..... 37
LUQUER, LEA MCI., AND MOSES, A. J. *Notes on Recent Mineralogical Literature* 247
Magnetic Properties of Iron and Steel at Liquid Air Temperatures. By C. C. Trowbridge 72
Mineralogy, Abstracts in. Notes on Recent Mineralogical Literature. By A. J. Moses and L. McI. Luquer..... 247
Morphology of Certain Organic Compounds. By A. F. Rogers..... 130
MOSES, ALFRED J., AND LUQUER, L. MCI. *Notes on Recent Mineralogical Literature* 247
MOSES, ALFRED J., AND ROGERS, A. F. *Formulæ and Graphic Methods for Determining Crystals in Terms of Coördinate Angles and Miller Indices*..... 1
New Graphical Methods in Crystallography. By A. F. Rogers 67
Notes on Recent Mineralogical Literature. By A. J. Moses and L. McI. Luquer 247
Obituary. Rood, Ogden N..... 171
On the Use of Influence Lines in Graphic Statics. By M. S. Falk.....119, 350, 440
Organic Compounds, Morphology of Certain. By A. F. Rogers..... 130
Production of Anisic Acid by the Oxidation of Aniseed Oil. By M. T. Bogert and C. H. Zieme 500
Radio-activity and Chemistry. By G. F. Barker 267
Rapid Method for the Determination of Arsenic in Arsenopyrite. By J. L. Danziger and W. H. Buckhout..... 400
RIEMER, CHIEF ENGINEER. *The Latest Progress in Shaft Sinking*..... 361
ROGERS, AUSTIN F. *The Morphology of Certain Organic Compounds*..... 130
" " *New Graphical Methods in Crystallography*..... 67
ROGERS, AUSTIN F., AND MOSES, A. J. *Formulæ and Graphic Methods for Determining Crystals in Terms of Coördinate Angles and Miller Indices*..... 1
Rood, Ogden N..... 171
Rossie Lead Veins. By C. H. Smyth, Jr..... 421
Shaft Sinking, Latest Progress in. By Chief Engineer Riemer..... 361
SMYTH, C. H., JR. *The Rossie Lead Veins* 421
Some New Work on Properties of Explosive Mixtures. By C. E. Lucke..... 37
Starch Molecule, Upon the Structure of. By F. E. Hale..... 145
Statics, Graphic, On the Use of Influence Lines in. By Myron S. Falk..119, 350, 440
Steel and Iron, see Iron and Steel.
Study of the Quantitative Determination of Antimony. By Lewis A. Youtz...135, 407
TITCOMB, H. A. *The Camp Bird Gold Mine and Mills*..... 56
TROWBRIDGE, C. C. *The Magnetic Properties of Iron and Steel at Liquid Air Temperatures*..... 72
TUCKER, S. A. *Laboratory Notes for Students in Practical Electrochemistry*... 429
Upon the Structure of the Starch Molecule. By F. E. Hale..... 145
WALLER, ELWYN. *Analytical Chemistry, Abstracts*.. 86
YOUTZ, LEWIS A. *A Study of the Quantitative Determination of Antimony*..135, 407
ZIEME, CARL H., AND BOGERT, M. T. *The Production of Anisic Acid by the Oxidation of Aniseed Oil*..... 500

VOL. XXIV. No. 1. NOVEMBER, 1902.

THE SCHOOL OF MINES QUARTERLY.

A

JOURNAL OF APPLIED SCIENCE.

BOARD OF EDITORS.

A. J. MOSES, Prof. of Mineralogy.
J. F. KEMP, Prof. of Geology.
R. PEELE, Adj. Prof. of Mining.
A. D. F. HAMLIN, Adj. Prof. of Architecture.
R. E. MAYER, Instructor in Drawing.
E. WALLER, Analytical Chemist.
JOS. STRUTHERS, Ph.D., Lecturer in Metallurgy.
I. H. WOOLSON, Instructor in Mechanical Engineering.
W. H. FREEDMAN, E.E.,
T. H. HARRINGTON, Tutor in Drawing

Managing Editor, R. E. MAYER,
Business Manager, T. H. HARRINGTON.

CONTENTS:

Formulæ and Graphic Methods for Determining Crystals in Terms of Coördinate Angles and Miller Indices. By Alfred J. Moses and Austin F. Rogers 1
Some New Work on Properties of Explosive Mixtures. By Charles E. Lucke 37
The Camp Bird Gold Mine and Mills. By H. A. Titcomb 56
New Graphical Methods in Crystallography. By Austin F. Rogers... 67
The Magnetic Properties of Iron and Steel at Liquid Air Temperatures. By C. C. Trowbridge 72
Abstracts in Analytical Chemistry. By Elwyn Waller 86
Alumni and University News 101
Book Reviews 115

COLUMBIA UNIVERSITY
NEW YORK CITY.

Registered at the New York Post Office as Second Class Matter.

TWO DOLLARS PER YEAR. FIFTY CENTS PER NUMBER.
All Remittances should be made payable to Order of "The School of Mines Quarterly."

Portland Cement

THE LAWRENCE CEMENT CO.

ESTABLISHED 1832.

ERNEST R. ACKERMAN, President

This Company has manufactured and sold during 70 years upwards of **20,000,000** barrels of Cement; marketing the product in all the principal cities of the United States, Canada, West Indies, Philippines and South America.

The old Custom House on Wall Street, built in 1835–37, and the new Custom House on Bowling Green, now under construction, were built with cement sold by this Company.

Used on the Old and on the New Stock Exchange in New York City, on the Brooklyn Bridge and New East River Bridge, and on the new Chamber of Commerce Building.

Detailed list of important Government Work, Reservoir Dams, Sidewalks, Fortifications, Bridges, Municipal Buildings and Railroad Work where "DRAGON" has been used, furnished on application.

DRAGON PORTLAND CEMENT Stands the Highest Requirements of Architects, Engineers and Builders.

SALES OFFICES:

NEW YORK, No. 1 Broadway. 15th and Market Sts., PHILA.

JENKINS BROTHERS' VALVES

Perfectly tight under all pressures of steam oils, or acids. Warranted to give satisfaction under the worst conditions.

Received the Highest Award **GOLD MEDAL** At the Pan-American Exposition.

Insist on having the genuine stamped with Trade Mark.

Jenkins Brothers, New York, Boston, Philadelphia, Chicago, London.

THE

SCHOOL OF MINES QUARTERLY.

VOL. XXIV. OCTOBER, 1902. NO. 1.

FORMULÆ AND GRAPHIC METHODS FOR DETERMINING CRYSTALS IN TERMS OF COÖRDINATE ANGLES AND MILLER INDICES.

BY ALFRED J. MOSES AND AUSTIN F. ROGERS.

CONTENTS.

	PAGE.
I. Introductory	2–4
Coördinate Angles	3
Stereographic Projection	4
Miller Indices	4
II. Measurement with the Two-Circle Goniometer	4–9
Principle of Two-Circle Measurement	4
The Two-Circle Goniometer	4
Obtaining the Readings v_0 and h_0	7
Adjusting a Crystal	7
Obtaining the Coördinate Angles	8
Sweeping the Field	8
Recording Measurements	9
III. Construction of the Stereographic Projection	9–11
Zone Circles	10
IV. Determination of Indices and Axial Elements	11–22
A. Determination of Indices by Zone Relations	11
B. Graphic Determination of Indices and Axial Elements	12
Principle of Graphic Determination by *hko*, *okl* and *hol* Planes	13
Isometric, Tetragonal and Orthorhombic Crystals	14
Hexagonal Crystals	16
Monoclinic Crystals	18
Triclinic Crystals	19
C. Calculation of Axial Elements from Measured Angles	22–24
Tetragonal Elements	22
Hexagonal Elements	22

Orthorhombic Elements 23
Monoclinic Elements 23
Triclinic Elements 24
D. Calculation of Coördinate Angles in Terms of Calculated Elements and Graphically Determined Indices 24–30
Isometric Coördinate Angles 25
Tetragonal Coördinate Angles 25
Hexagonal Coördinate Angles 26
Orthorhombic Coördinate Angles 26
Monoclinic Coördinate Angles 27
Triclinic Coördinate Angles 28
E. Transformations 30–32
Transformation to any New Polar Plane and New Meridian 30
Special Cases 31
Graphic Check on Transformation 31
Transformation by Indices 31
F. Twinned Crystals 32
V. Obtaining Coördinate Angles from Interfacial Angles 32–36
One Circle Measurement 32
Projection from Interfacial Angles 33
Isometric System 33
Tetragonal System 34
Hexagonal System 34
Orthorhombic System 35
Monoclinic System 35
Triclinic System 36

I. INTRODUCTORY.

The principal advantages of two-circle measurement are:

(*a*) That constants for each face may be obtained, with one adjustment of the crystal, whereas, in one-circle measurements, a readjustment is necessary in each zone. This readjustment in the case of zones of little prominence is often difficult.

(*b*) These constants, two for each face, determine the position of each face with respect to every other face. For n faces there are only $2n$ angles, whereas for the same completeness with one-circle measurements $n(n-1)$ angles would be needed.

As developed by Goldschmidt, the constants obtained by two-circle measurements lead to a new system of symbols, and are used with the gnomonic projection instead of with the more compact and convenient stereographic projection.

It is our purpose in this article to develop a convenient and simple method for obtaining the geometrical constants of a crystal from the two-circle angles, using Miller indices, the stereographic

projection and graphic solutions checked by calculations. At the end of the article formulæ have been given by which the interfacial angles obtained by one-circle measurement may be converted into the more convenient coördinate angles of two-circle measurement.

The following definitions of coördinate angles, stereographic projection and Miller indices are needed:

Coördinate Angles.

The crystal is assumed to lie within a sphere, the centers of the sphere and the crystal coinciding. The angles between radii normal to crystal faces (the normal interfacial angles) are measured on the great circles through the radii. The "pole" of any face, that is the point where the face normal pierces the sphere surface, may be located not only by its angular distance from other face poles, but also by two angles similar to latitude and longitude. One of

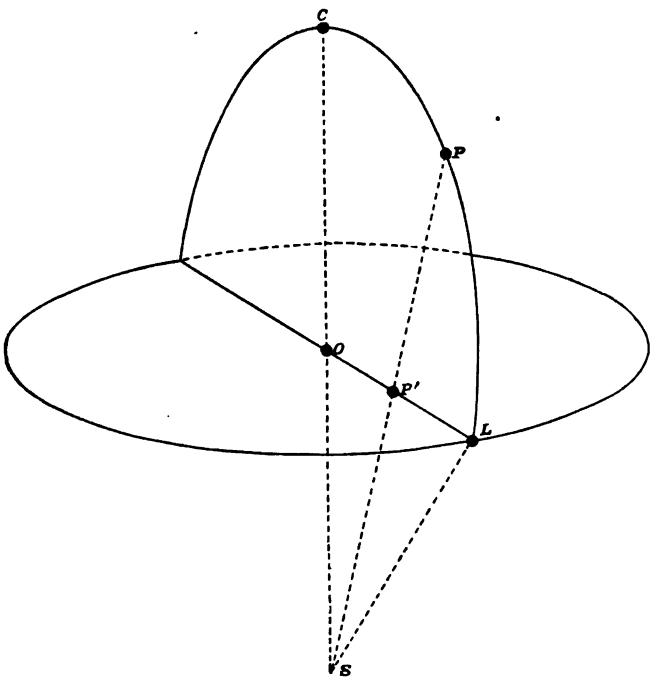


FIG. 1.

these, denoted by ρ, is measured from a chosen "polar plane" upon the great circle through the face pole and the polar plane, the other,

denoted by φ, is the angle between that great circle and a chosen meridian and is measured on the equatorial circle. These two angles φ and ρ are the "coördinate angles" of the crystal face.

Stereographic Projection.

The imaginary sphere with its face poles and circles is most conveniently projected upon a diametral plane, each face pole P, Fig. 1, being projected at P' the intersection of the line from P to the south pole S. Similarly C is projected at O and L at L.

In such a so-called "stereographic projection" all circles are projected as circles, the pictorial effect is good, the distortions are not great and the plotting can be done rapidly and so exactly that the projection may be graphically solved with great accuracy.

Miller Indices.*

The symbols for a crystal face are usually based upon the relative lengths of the intercepts which the face makes on certain imagined axes. If a, b, and c are the intercepts of some chosen unit face and OH, OK and OL are the corresponding intercepts of some other face of the crystal on the same axes, then the Miller indices hkl of this face are:

$$h = \frac{a}{OH}, \quad k = \frac{b}{OK}, \quad l = \frac{c}{OL}.$$

II. MEASUREMENT WITH A TWO-CIRCLE GONIOMETER.

Principle of Two-Circle Measurement.

If the collimator axis and the telescope axis lie in a horizontal plane and the crystal face is at their intersection, a ray from the collimator will be reflected *into* the telescope if the face is first made vertical by a rotation about a horizontal axis and is then placed at right angles to the line bisecting the angle between the axes of collimator and telescope, by a rotation about a vertical axis. These two rotations furnish the readings from which the coördinate angles are obtained.

The Two-Circle Goniometer.

In Fig. 2 is shown the goniometer of Goldschmidt, Model 1898, and in Figs. 3 and 4 a later modification of the objectives. The ver-

* To obtain Miller indices from the Weiss' symbols, take the reciprocals of the Weiss coefficients and clear of fractions. For instance $a : 2b : 3c$ becomes 1, ½, ⅓ or 632.

tical circle **V** is * attached to and revolves with the horizontal circle **H.** The telescope **F** turns independently around the axis of the

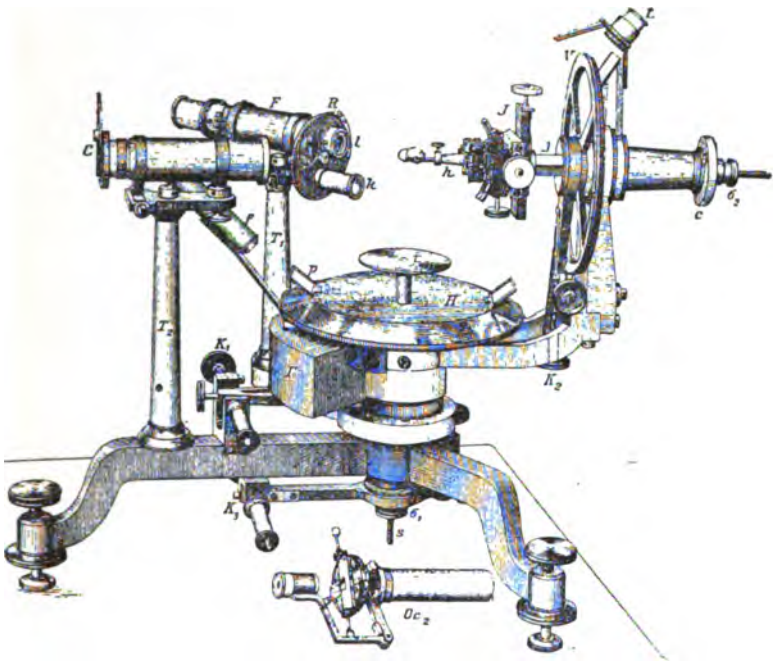


FIG. 2.

horizontal circle, but throughout any measurement is clamped. The collimator **C** is fixed. The axes of all four, **V, H, F** and **C,** intersect at the same point and at this point the crystal is centered.

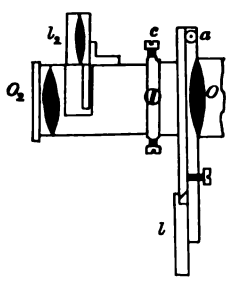


FIG. 3.

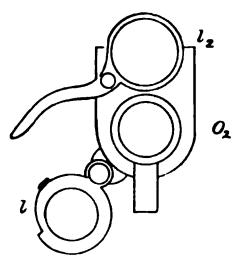


FIG. 4.

The centering and adjusting devices of the crystal carrier **J** are the usual three motions of translation at right angles to each other

* *Zeit. f. Kryst,* **21**, 210–232, 1892, also **29**, 333–345, 1898.

and the two motions of rotations about arcs of concentric spheres. The rough centering may be done with the eyepiece removed and the finer centering and adjusting by swinging in the extra lens *l*, all as in one-circle measurement.

The revolving disc of objectives, **R**, is not now used, but is replaced by the hinged device shown in Figs. 3 and 4. For crystals of fair size with good faces, the ordinary eyepiece, the objective **O**, the swing lens *l*, and the largest of the four signals shown in Fig. 5 are first used and then the smallest signal which will give a sharp image.

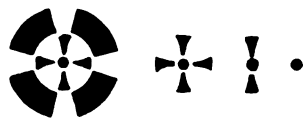


FIG. 5.

For minute faces the ordinary eye piece is replaced by Oc_2 shown at the bottom of Fig. 2. *l* is swung to one side and the objective shown in Figs. 3 and 4 is dropped in front of **O**. By means of l_2 the crystal may be brought into focus and if a magnified view is desired l_2 is raised and the lens on Oc_2, Fig. 2, swung into position.

In Fig. 6 is shown the two-circle goniometer of von Federow, model 1, as made by Fuess.* In this instrument the telescope

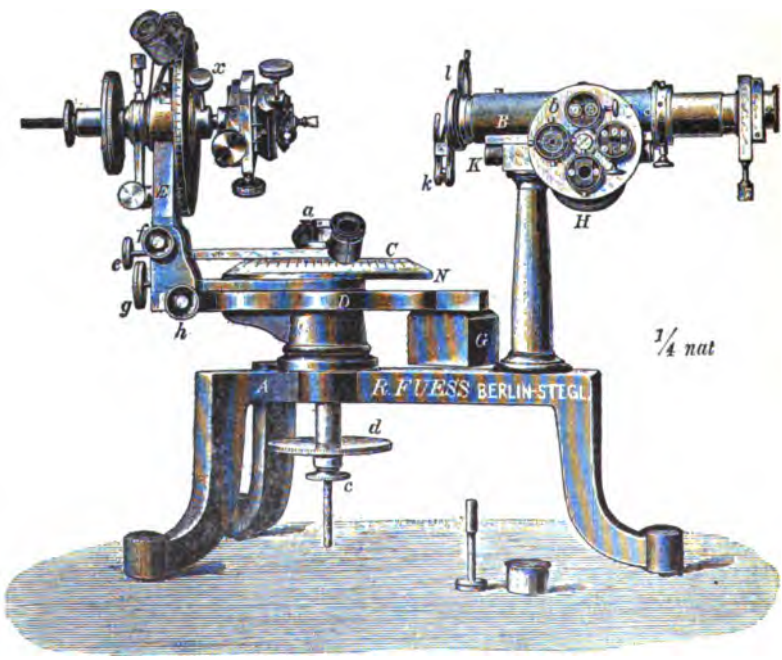


FIG. 6.

* *Zeit. f. Kryst.*, 21, 603–616, 1893.

is also the collimator. The signals are varied by the disc *b* and the light entering at the focal plane of the objective, passes through a small total reflecting prism and emerges as parallel rays. The eyepiece has an iris blende.

Czapski * also describes a two-circle goniometer with an auto-collimator.

Obtaining the Readings v_0 and h_0.

The reading v_0 is the reading of the vertical circle at which the faces of a selected zone at right angles to the circle yield reflections. It is independent of the position of the telescope. The chosen zone may be called the "prime meridian."

The reading h_0 is the reading upon the horizontal circle of a plane (the "polar plane") parallel to the vertical circle. The reading varies with the position of the telescope and is determined as follows:

The telescope is clamped at a convenient angle to the collimator and a plane surface is centered and made approximately parallel to **V**. By turning both **V** and **H** a reflection is obtained and **V** and **H** are read. **V** is then turned 180° and clamped and **H** is turned until a reflection is again obtained and **H** is again read. The mean of these two readings on **H** is h_0, *for that particular position of the telescope.* By setting **H** at h_0 and recentering the signal by the arcs of the crystal carrier the signal should be stationary when **V** is turned; if not stationary a new mean value should be obtained as before.

Adjusting a Crystal.

The desired position is with the vertical axis of the crystal at right angles to **V**. Sometimes it is more convenient to place another zone normal to **V** and later transform the results.

1. If the "polar plane" is present, as a crystal face or cleavage, it is placed approximately parallel to **V** and centered, **H** is set at h_0, and clamped and the signal brought into view and centered *solely* by the arcs of the crystal carrier **J**, Fig. 2. The signal from the polar plane must remain unmoved during a complete revolution of **V**.

2. If the "polar plane" is not present **H** is clamped at $h_0 + 90°$ or at $h_0 - 90°$, a prism edge is made parallel to the horizontal cross-

* *Zeit. f. Instrumentk.*, 13, 1, 242, 1893. Abst. *Zeit. f. Kryst.*, 25, 620.

hair and the signal is centered as before by the arcs on the carrier **J**. If properly centered the signals from all the prism faces will be accurately centered by turning **V**.

3. If neither "polar plane" nor prismatic zone are available but the polar plane lies in a known zone at an angle α to an occurring face an edge of the zone is made to coincide with the vertical cross-hair, **V** is then clamped and **H** set at $h_0 + \alpha$ and the face brought to reflection by the arcs on **J**.

Obtaining the Coördinate Angles.

After the values of h_0 for the polar plane and v_0 for the prime meridian, have been obtained, the centered signal from *any* other face, if obtained by rotating **V** and **H** without changing the position of the centering screws or the position of the telescope, will yield two other readings v and h and the coördinate angles of the face will be $\varphi = v - v_0$ and $\rho = h - h_0$ or $h_0 - h$.

Every face will give signals for two positions, these however yield the same φ and ρ as follows:

$$v - v_0 = \varphi, \quad v' = v_0 = \varphi + 180^\circ$$
$$h - h_0 = \rho \quad h_0 - h' = \rho$$

Averaging these tends to balance inaccuracies in adjustment.

The values of φ and ρ are independent of the position of the telescope. φ is measured on **V**, from the prime meridian from 0° to 180° and, conventionally, is positive in the direction of the hands of a watch and negative in the opposite direction. ρ is measured on **H**, from the polar plane from 0° to 90° and is always positive.

Except in isometric crystals, faces of the same form have the same ρ, and the values of φ often differ by regular intervals, as 30°, 45°, 60°, or 90°.

Sweeping the Field.

To insure the complete measurement of any crystal, including all minute faces, the following plan may be used.

With the extra eyepiece Oc_2 and the extra objective O_2, Figs. 3 and 4, determine the number of degrees during which any portion of the largest signal is in the field. This will be about ten degrees. Starting with some prominent zone, such as the prime

meridian, turn **H** ninety degrees each side of h_0, centering each observed signal and reading **V** and **H**, then turn **V** back to the meridian and continue the search.

This is repeated for a second meridian at ten degrees to the first, that is with **V** at ten degrees to its former position, then for a third meridian at twenty degrees to the first, and so on through 180 degrees. Or by continuing through 360 degrees a second set of readings may be obtained for the same faces as explained on page 8.

Recording Measurements.

A rough sketch is made showing prominent faces. As measuring proceeds the faces are numbered successively and recorded on the sketch and the more minute faces sketched in. Later φ and ρ are calculated and the letter and symbol are only entered after solving the projection. Convenient entries for signal are *g.*, *f.*, *p.*, for good, fair, poor.

The essential record headings are about as follows:

ATACAMITE No. 1.

$v_0 = 124° 26'$, $h_0 = 112° 5'$.

Signal.	No.	Letter.	Indices.	v	h	ϕ	ρ	Remarks.
g.	1	*n*	121	161° 40′	174° 08′	37° 14′	62° 03′	

III. CONSTRUCTION OF THE STEREOGRAPHIC PROJECTION.

The methods of plotting have been much simplified by the use of the protractors described by Penfield,* which may be obtained at small cost.†

Usually the projection is made upon a plane at right angles to the vertical axis of the crystal. In such a projection, Fig. 7, any face *P*, for which $\varphi = 19°35'$ and $\rho = 74°51'$, lies on that radius *ZN* which is at an angle of 19°35′ to the prime meridian $B\bar{B}$, and at a distance *ZP* from the "polar plane" or center, which is the stereographic value of 74°51′, that is, equal the tangent of one half ρ.

* *Am. Jour. Sci.* (4), 11, 1–24 and 115–144. 1901.

† E. L. Washburn & Co., New Haven, Conn.

This stereographic ρ is obtained directly from protractor No. I.* Similarly the face R with $\varphi = 64°48'$ and $\rho = 53°10'$ and M with $\varphi = 64°48'$ and $\rho = 90°$ are plotted.

Zone Circles.

A series of faces which intersect in parallel edges, constitutes a "zone," and the poles of these faces are all projected in the same great circle. For instance B, P, R, K and $\overline{B}$ of Fig. 7.

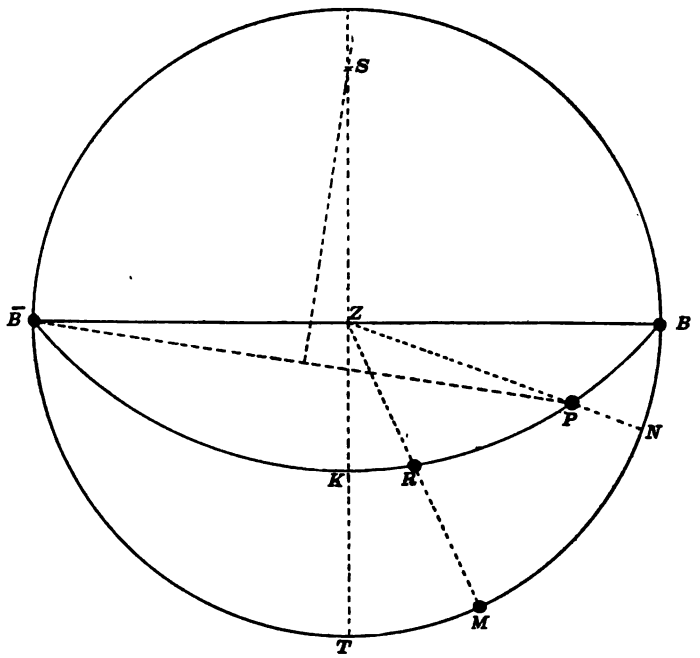


FIG. 7.

Zones are *discovered* by protractor No. IV., † which is pivoted at the center and revolved until a series of poles are seen to coincide with one of the arcs of the protractor.

* The protractor No. I. is a scale 14 cm. long on which the graduations are "stereographic degrees," that is any degree a is at a distance $\tan \frac{a}{2}$ from the center. It therefore will measure *on any diameter* the true angle between projected poles, or conversely if the angle and one pole is known it will locate the second pole.

† Protractor No. IV. of Penfield consists of a sheet of celluloid on which are printed stereographically projected semicircles. Every tenth degree is a heavier line and all pass through the same points and range from the straight line to the true semicircle, with a radius of seven centimeters.

It is customary to draw the more prominent zones, and since all zones are projected as arcs of circles and always intersect the equatorial in two points, the extremities of the same diameter, the center will be on the radius normal to this diameter and the length of the zone radius will be found by counting on protractor IV. the stereographic degrees from the equatorial to the zone and finding the corresponding radius upon a special scale. For instance protractor No. IV. shows, in Fig. 7, that the zone through P and R intersects the equatorial in B and $\overline{B}$ and counting from the circumference, the zone is a little beyond the 39 degree arc. The radius corresponding to this arc is found on the Penfield scale No. 1. Or the center S of the desired circle may be found directly at the intersection of the normals bisecting B $\overline{B}$ and P $\overline{B}$.

IV. DETERMINATION OF INDICES AND AXIAL ELEMENTS.

The position of the pinacoids and the unit faces being known in the projection, it is possible to determine graphically the axial elements and the indices of all other occurring faces with sufficient accuracy to indicate the true rational indices. Later calculations check these so that one series of calculations is saved and the graphic results also serve as a check upon the others.

A. DETERMINATION OF INDICES BY ZONE RELATIONS.*

In any zone through a pinacoid the ratio of the two indices, which are zero for the pinacoid, is constant for all faces of the zone:

---

* The indices of a face at the intersection of *any* two zones may be determined from the indices of two faces in each zone. Let hkl and $h'k'l'$ be two faces in a zone. The direction of their intersection is expressed by [uvw] in which $u = kl' - lk'$, $v = lh' - hl'$ and $w = hk' - kh'$. These values are easily found by twice writing the indices, striking off the end terms and reading down alternately from left to right and from right to left, thus:

$$\begin{array}{c|cccc|c} h & k & l & h & k & l \\ & \times & \times & \times & & \\ h' & k' & l' & h' & k' & l' \end{array}$$

The values of [u′v′w′], the symbol of the second zone, are found in the same manner.

The values of (pqr), the desired indices, result from an exactly similar cross multiplication of [uvw] and [u′v′w′].

If a face lies in a zone [uvw] its indices must satisfy the equation $pu + qv + rw = 0$.

Zone through	*Constant*
001	$\frac{h}{k}$
100	$\frac{k}{l}$
010	$\frac{h}{l}$

The indices of a face at the intersection of two such zones will result if in each zone a second face is known. The desired values may be obtained by writing the indices of the two known faces omitting the term in each not part of the constant ratio, and then multiplying the corresponding pair for one index and diagonal pairs for the other two indices.

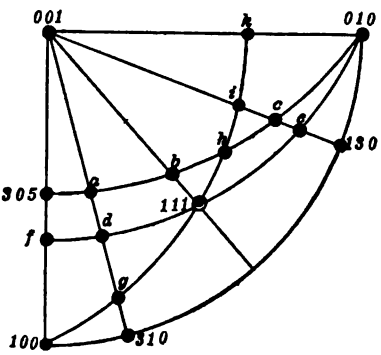


FIG. 8.

EXAMPLE. In Fig. 8 let the pinacoids and (111), (310), (305), and (130), be known, to find the indices of planes projected at *a* *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *k*. All calculations are either like *h* in zones [010 305] and [100 111], or like *i* in zones [001 130] and [100 111]

$$\begin{array}{r} 3\ -\ 5 \\ \times\ |\ \\ -\ 1\ 1 \\ \hline 3\ 5\ 5 \end{array} \quad h = (355),$$

$$\begin{array}{r} 1\ 3\ - \\ \diagdown\ |\ \diagup \\ -\ 1\ 1 \\ \hline 1\ 3\ 3 \end{array} \quad i = (133).$$

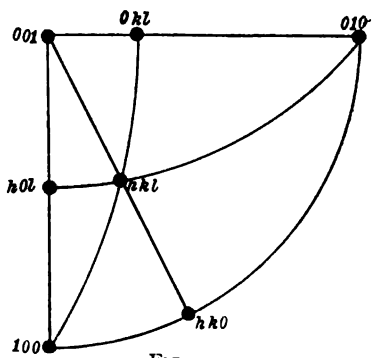


FIG. 9.

Similiarly $a = (315)$, $b = (335)$, $c = (395)$, $d = (313)$, $e = (131)$, $f = (101)$, $g = (311)$ and $k = (011)$. By considering zones through *a*, *b*, *c*, *d*, etc., other indices result.

B. GRAPHIC DETERMINATION OF INDICES AND AXIAL ELEMENTS.

NOTE.—For any face *hkl* the zone circles through 001, 100 and 010, Fig. 9, are found by protractor IV. and the coördinate angles *

* The values of ρ for 0*kl* and *h*0*l* are respectively η_0 and ξ_0 of corresponding *hkl* in Goldschmidt's "Krystallographische Winkeltabellen."

of the corresponding *hk*o, o*kl* and *h*o*l* planes are found by protractor I.

Principle of Graphic Determination by *hk*o, o*kl* and *h*o*l* Planes.

If XY, Fig. 10, is a quadrant of any zone, O, the center, and P and P', two faces of that zone, then the intercepts RT and RT' made on any line RW normal to OX by the face-normals OP, OP' are in the ratio of the tangents of the angles TOR and $T'OR$ respectively, *i. e.*,

$$\frac{RT'}{RT} = \frac{\tan T'OR}{\tan TOR}.$$

If OX and OY are axes RT and RT' are in the ratio of the Miller indices, for:

Let the dotted lines SM and SM' be drawn parallel to the crystal faces of which P and P' respectively are the poles.

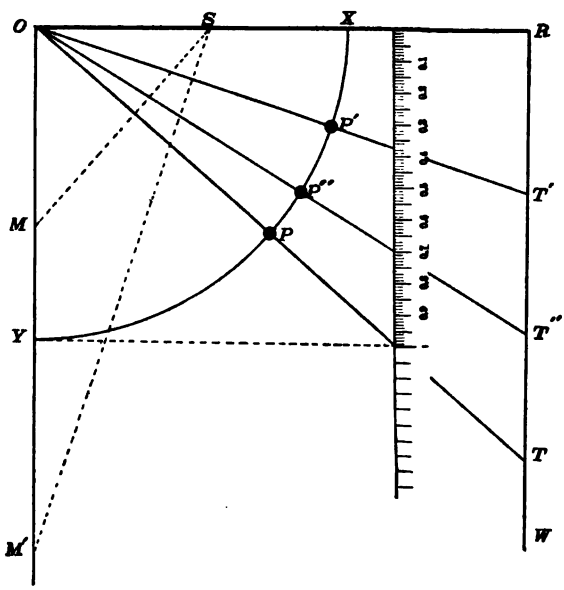


FIG. 10.

Then the angles $OMS = TOR$ and $OM'S = T'OR$, but

$$\frac{\tan T'OR}{\tan TOR} = \frac{\tan OM'S}{\tan OMS} = \frac{OM}{OM'};$$

hence

$$\frac{RT'}{RT} = \frac{OM}{OM'}.$$

That is, if the intercepts of the faces corresponding to P and P' on OX are made equal, their intercepts RT and RT' on RW are as the reciprocals of their intercepts OM and OM' on Y, that is, in the ratio of the indices.

This ratio is graphically obtained as follows:

RW is so drawn that RI is unity of some decimal scale,* then RT' and RT'', determined by radii through planes P' and P'', are given directly on the scale in terms of RT. In the drawing $RT' = 0.375$ and $RT'' = 0.7$.

The relations are simplest when P is a unit plane. Then the readings on the scale line are the ratios $\frac{h}{k}$, $\frac{k}{l}$, or $\frac{h}{l}$.

Isometric, Tetragonal and Orthorhombic Crystals.

Determination of the ratio $\frac{h}{k}$. The construction for the *hk*o planes is made in the first quadrant, the face normals having already been laid off at the φ angles.

EXAMPLE, in Fig. 11 let M be 110. Taking the radius as unity of the scale and finding T as before, the scale line RT is drawn. Then the ratios $\frac{h}{k}$ for the prisms and pyramids are as follows:

Prism m and pyramids θ, f, g, z and τ, $\frac{h}{k} = 1$.

Prism h and pyramid t, $\frac{h}{k} = \frac{1}{2}$.

Prism k and pyramid s, $\frac{h}{k} = \frac{1}{3}$.

If the intersection of a given face-normal with the scale line is beyond the limit of the paper the ratio $\frac{k}{h}$ may be obtained from a second scale line R_1T_1 drawn through a point T_1 the intersection of BT_1 and the unit radius.

EXAMPLE prism λ, $\frac{k}{h} = \frac{1}{2}$; $\frac{h}{k} = 2$. Prism N, $\frac{k}{h} = \frac{1}{3}$; $\frac{h}{k} = 3$.

Determination of ratios $\frac{k}{l}$ *and* $\frac{h}{l}$. The constructions for the *okl* and *hol* planes are conveniently made in the fourth quadrant, the ρ angles being laid off from A'. The radii CT' and CT'' for the unit domes determine the scale lines for the ratio $\frac{k}{l}$ and $\frac{h}{l}$ respectively.

* The radius of the circle is a convenient unit.

EXAMPLE, Fig. 11,

okl planes, v, $\frac{k}{l} = \frac{1}{8}$ o, $\frac{k}{l} = 1$,

hol planes, e, $\frac{h}{l} = \frac{1}{8}$ d, $\frac{h}{l} = \frac{1}{2}$.

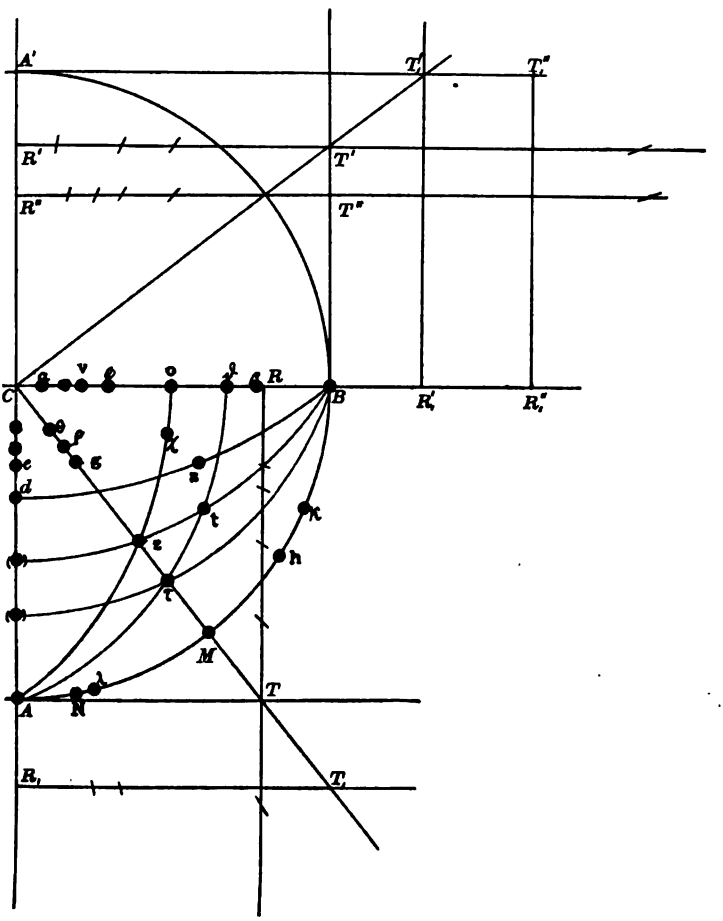


FIG. 11.

The *hkl* planes.—Either find $\frac{k}{l}$ and $\frac{h}{l}$ by a graphic determination of the corresponding *okl* and *hol* or if pyramids in the same zone are compared, obtain the indices directly from ρ.

EXAMPLE. The *hkl* plane *s* is 132 for ρ of the corresponding *okl* gives $\frac{k}{l} = \frac{3}{2}$, and from *hol* gives $\frac{h}{l} = \frac{1}{2}$, or in comparison with known pyramid *hkl* (131) gives $\frac{l}{l'} = \frac{2}{1}$.

As in *hko* planes, a second scale gives may be drawn from T_1' or T_1'' parallel to $A'C$ for determining the ratio $\frac{l}{k}$ or $\frac{l}{h}$.

Determination of Axial Elements. Orthorhombic. Taking $b = 1 = CA$, then $AT = a$ on the same scale. Similarly, if $b = 1 = CA$, then $c = A'T_1'$. Similarly, if $b = 1 = CB$, then $BT'' = \frac{a}{c}$.

Tetragonal. c as in orthorhombic. If ρ of 111 is laid off $A'T_1' = 1.4142\,c$.

Hexagonal Crystals.

For any face $hk\bar{i}l$ the zone circles through 0001, $10\bar{1}0$, and

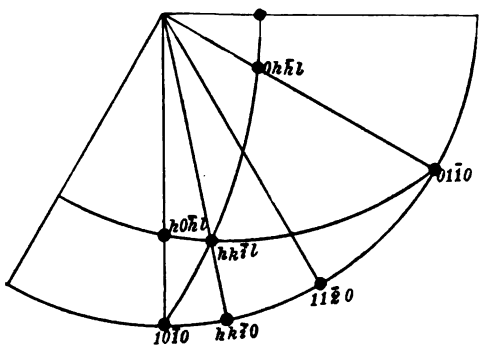


FIG. 12.

$01\bar{1}0$, Fig. 12, and the coördinate angles of the corresponding $hki\bar{o}$, $oh\bar{i}l$, and $ho\bar{i}l$ planes are found by protractors I. and IV.

All faces in the zones through 0001, $10\bar{1}0$, and $01\bar{1}0$ have constant ratios for the indices which are zero in the planes mentioned.

For a zone through $00(0)1$, $\frac{h}{k}$ is constant for all faces.

For a zone through $10(\bar{1})0$, $\frac{k}{l}$ is constant for all faces.

For a zone through $01(\bar{1})0$, $\frac{h}{l}$ is constant for all faces.

The method of finding these ratios is essentially as described on page 12, but it is convenient to omit the third index.

EXAMPLE. $hk\bar{i}l$ lies in the zone $10\bar{1}0 : 02\bar{2}1$ and also in the zone $01\bar{1}0 : 11\bar{2}\bar{1}$. By the first zone $\frac{k}{l} = \frac{2}{1}$, by the second zone $\frac{h}{l} = \frac{1}{1}$. Writing the three members hkl, omitting $\bar{i}$

$$\begin{array}{r} -\ 2\ 1 \\ \times\ \ | \\ 1\ -\ 1 \\ \hline 1\ 2\ 1 \end{array} \qquad hkl = 121 \qquad hk\bar{i}l = 12\bar{3}1.$$

Determination of ratio $\frac{h}{k}$. From the projections of $01\bar{1}0$ and $10\bar{1}0$, R and R', Fig. 13, draw lines RT and $R'T$ parallel to CR'

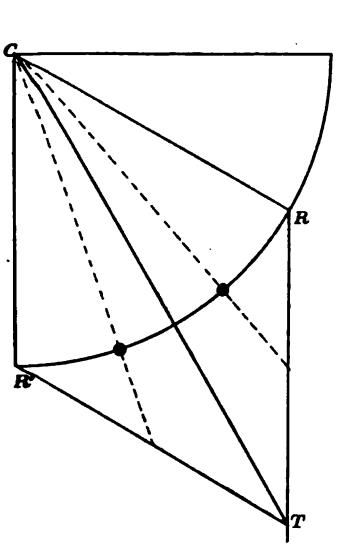


FIG. 13.

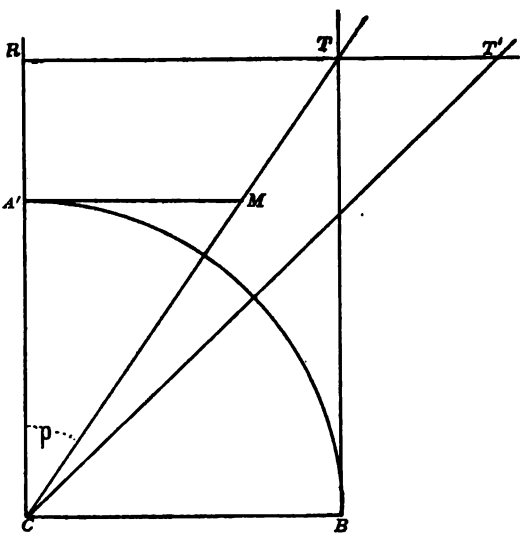


FIG. 14.

and CR respectively. Intersections of radii through $hk\bar{i}l$ or $hki0$ on RT will give the ratio $\frac{h}{k}$ directly as $RT = CR =$ unity of scale. Similiarly radii on $R'T$ will give $\frac{k}{h}$.

Determination of ratio $\frac{k}{l}$ or $\frac{h}{l}$. Lay off the angles from A'. If CB, Fig. 14, is the unit of the scale, the intersection 7 of the

tangent and the radius through the unit face will give $RT = 1$ and other intercepts on the scale line such as RT' will be $\frac{h}{l}$. This is true in any vertical zone if ρ of the plane in that zone in which $\frac{h}{l}$ or $\frac{k}{l}$ is used to determine the position of the scale line RT.

Determination of the Axial Elements. If ρ of $11\bar{2}1$ is used and $CA' = a$, then the tangent $A'M = \dot{c}$, measured on the scale. See Fig. 14. If ρ of $10\bar{1}1$ is used, $A'M \times 0.866 = \dot{c}$.

Monoclinic System.

Determination of Ratio $\frac{h}{k}$. Prisms are determined as in the orthorhombic system. For pyramids the corresponding prisms are found by protractor IV. on zones through 001 which are no longer radial.

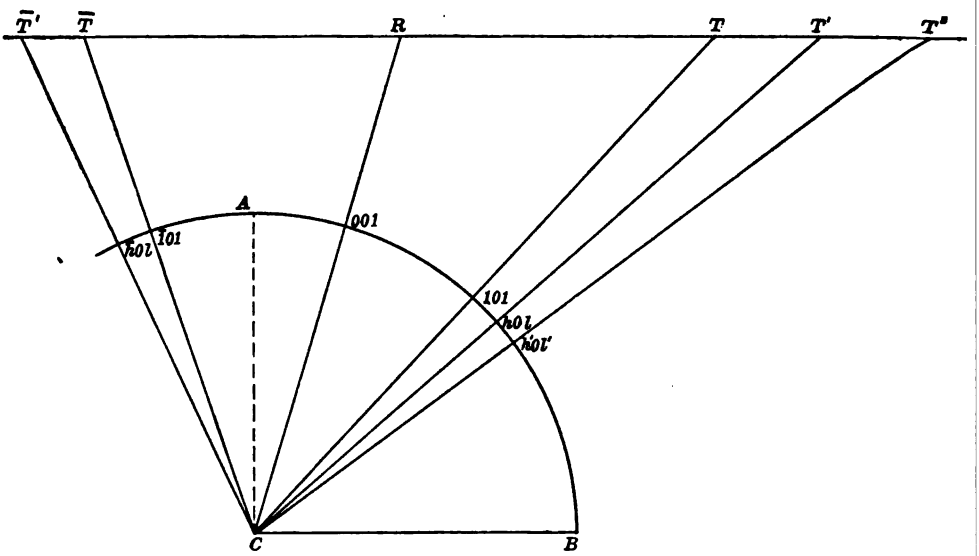


FIG. 15.

Determination of Ratio $\frac{h}{l}$. In * the fourth quadrant draw radii at

* Proof. Let XY (Fig. 18) be face 101, $X'Y$, face $h0l$, OY normal to OR, the axis $\dot{a}$ and OC, the axis $\dot{c}$. The triangles TOR and XOY, are similar, hence $\frac{RT}{OR} = \frac{OX}{OY} = \frac{c}{a_1}$. Similarly $\frac{RT'}{OR} = \frac{h}{l}\frac{c}{a}$. Hence $\frac{RT'}{OR} \times \frac{OR}{RT} = \frac{h}{l}\frac{c}{a} \times \frac{a}{c}$. $\therefore \frac{RT'}{RT} = \frac{h}{l}$. When $RT = 1$, $RT' = \frac{h}{l}$.

angles ρ to CA for planes 001, 101, *hol*, etc., Fig. 15. Draw a line parallel to CB such that $R1$ = unit of scale line. Then $RT' = \frac{h}{l}$, $R1'' = \frac{h'}{l'}$ $R\bar{1}$, $= \bar{1}$, $R\bar{T}' = \frac{h}{l}$ on the same scale.

Determination of Ratio $\frac{k}{l}$.—Graphically find ρ of an imaginary corresponding face M on ZB, Fig. 16. Then determine as in the orthorhombic system.

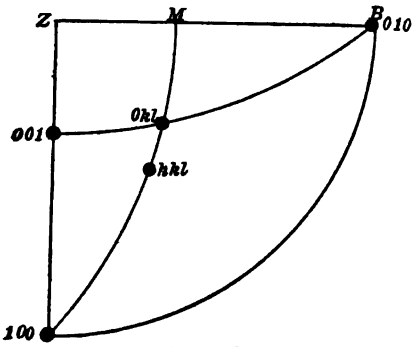


FIG. 16.

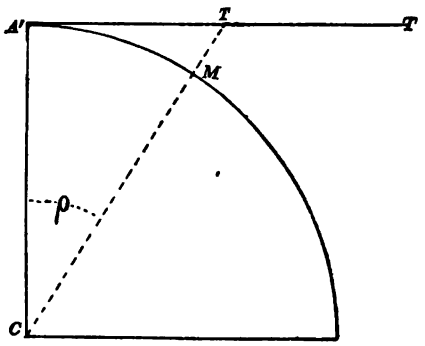


FIG. 17.

Determination of the Axial Elements. For β, measure the arc 100 : 001 with protractor No. 1. For a and c lay off in the fourth quadrant, Fig. 17, ρ of an imaginary face, M, found as described

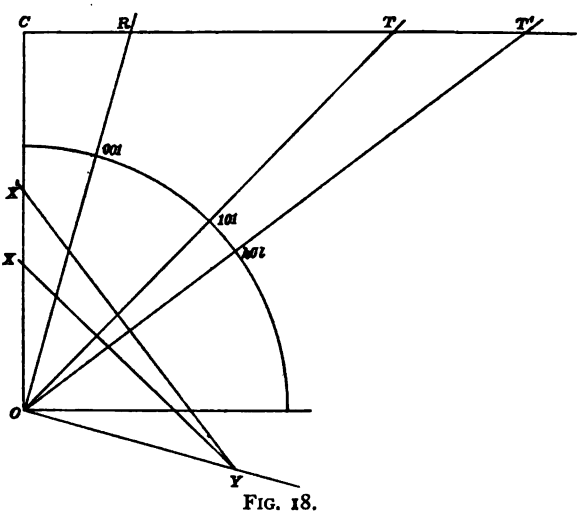


FIG. 18.

above, then if $CA' = b = 1$, the tangent $A'T = c$. In determination of the ratio $\frac{h}{l}$, Fig. 15, if $RT = 1$, $CR = \frac{a}{c}$.

Triclinic System.

Determination of Ratio $\frac{h}{k}$.—Draw in the first quadrant radii at angles φ to ZB, Fig. 19, for planes 110, hk0, etc. Draw a line parallel to ZA so that RT = unity of the scale line, then $RT' = \frac{h}{k}$ and $RT'' = \frac{h'}{k'}$. ($h'k'$0 corresponding to $h'k'l'$ is on the great circle through C.)

Determination of Ratio $\frac{k}{l}$.—Center protractor IV., its diameter coinciding with diameter AA'. Determine on what great circle

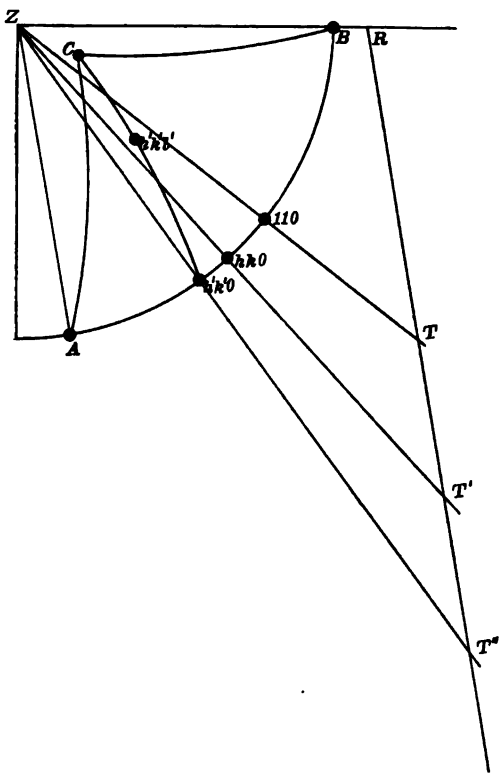


FIG. 19.

(measuring in degrees from center) 001 and any face involving a ratio $\frac{k}{l}$ lies. These distances in stereographically projected degree are angles for imaginary planes e, f, g, h, etc., projected on the diameter normal to AA'.

Draw radii, Fig. 20, at angles ρ from the vertical for e, f, g, h. Draw a line parallel to OB so that RT = unity of scale, then $RT' = \frac{k}{l}$; $RT'' = \frac{k'}{l'}$.

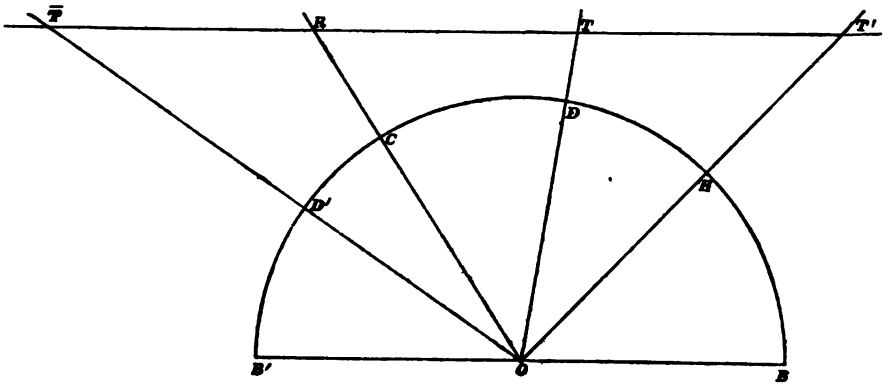


FIG. 20.

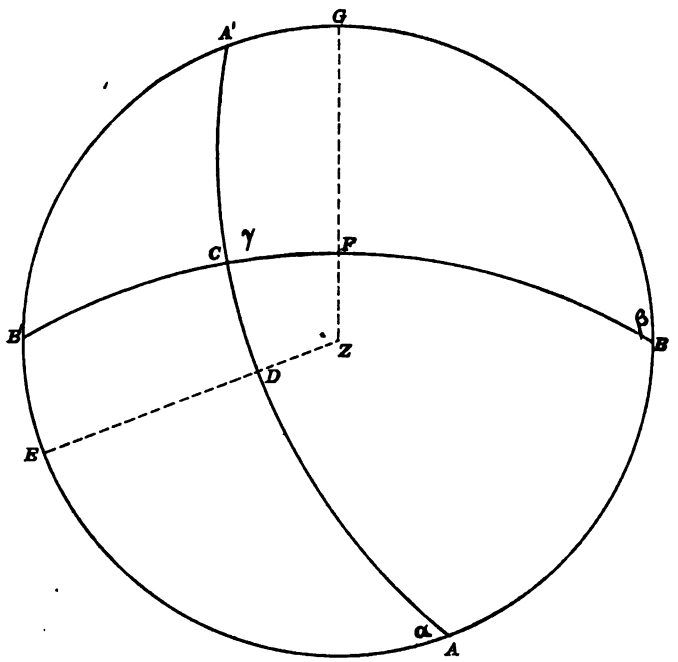


FIG. 21.

Determination of Ratio $\frac{h}{l}$.—As before, but *e*, *f*, *g*, *h*, are now imaginary planes on a line normal to *BB'*.

Determination of Axial Elements.—Measure α and β by protractor No. 1 on radii 90° from desired angles. For instance in Fig. 21 $\alpha = DE$ if $AE = 90°$; $\beta = FG$ if $BG = 90°$, γ is equal to the angle between the tangents to the arcs *AA'* and *BB'* at *C*. In constructions for $\frac{k}{l}$ and $\frac{h}{l}$, Fig, 20, if $R1 = 1$, $OR = \frac{b}{c}$ and $\frac{a}{c}$ respectively.

C. CALCULATION OF AXIAL ELEMENTS FROM THE MEASURED ANGLES.

While for the purposes of identification the graphical solution will often suffice, all descriptions of new crystals or other work for record requires calculation of the axial elements from as many measured angles as possible and an averaging in which proper weight is given to sharpness of reflection and other considerations.

Tetragonal Elements. $h > k$, l is index on $\dot{c}$.

okl $\qquad \dot{c} = \frac{l}{k} \tan \rho.$

hhl $\qquad \dot{c} = \frac{l}{h}\, 0.7071 \tan \rho.$

khl* $\qquad \dot{c} = \frac{l}{k} \sin \varphi \tan \rho.$

Hexagonal Elements. $h > k$; $h + k = i$; l is index on $\dot{c}$.

hoh̄l $\qquad \dot{c} = 0.86602 \frac{l}{h} \tan \rho.$

h·h·2̄h·l $\qquad \dot{c} = \frac{l}{2h} \tan \rho.$

hkī̄l $\qquad \dot{c} = \frac{l}{i} \tan \rho \cos (30° - \varphi).$

Comparison with Goldschmidt's Orientations G_1 *and* G_2.

$$G_1 \begin{cases} \varphi = \varphi\,;\ \rho = \rho\,; & hk\bar{i}l = hkil\,; \\ \dot{c} \text{ Goldschmidt} = \dot{c}\sqrt{3} \text{ of formulæ.} \end{cases}$$

* Face of form $\{hkl\}$.

$$G_2 \begin{cases} \dot{c} = \dot{c}\,;\ \rho = \rho\,;\ l = l. \\ \varphi \text{ Goldschmidt} = 30^\circ - \varphi \text{ of formulæ.} \\ h \text{ Goldschmidt} = h + 2k \text{ of formulæ.} \\ k \text{ Goldschmidt} = h - k \text{ of formulæ.} \end{cases}$$

Orthorhombic Elements.

hko $$\breve{a} = \frac{h}{k} \cot \varphi.$$

okl $$\dot{c} = \frac{l}{k} \tan \rho.$$

hol $$\frac{\breve{a}}{\dot{c}} = \frac{h}{l} \cot \rho.$$

hkl $$\breve{a} = \frac{h}{k} \cot \varphi.$$

$$\dot{c} = \frac{l}{k} \cos \varphi \tan \rho.$$

Monoclinic Elements.

oox $$\beta = 90^\circ - \rho.$$

hko $$\dot{a} = \frac{h}{k} \cdot \frac{\cot \varphi}{\sin \beta}$$

okl $$\dot{c} = \frac{l}{k} \cos \varphi \tan \rho.$$

$$\cot \beta = \dot{c} \cdot \frac{k}{l} \tan \varphi.$$

hol $$\frac{\dot{a}}{\dot{c}} = \frac{h}{l} \cdot \frac{\cos \rho}{\cos (\beta + \rho)}$$

$\bar{h}$***ol*** $$\frac{\dot{a}}{\dot{c}} = \frac{h}{l} \cdot \frac{\cos \rho}{\cos (\beta - \rho)}.$$

hkl $$\dot{c} = \frac{l}{k} \cos \varphi \tan \rho.$$

$$\tan \rho^{h0l} = \sin \varphi \tan \rho\,;\ \text{then } \frac{\dot{a}}{\dot{c}} \text{ from } \textbf{\textit{hol}}.$$

$\bar{h}$***kl*** $$\dot{c} = \frac{l}{k} \cos \varphi \tan \rho.$$

$$\tan \rho^{\bar{h}0l} = \sin \varphi \tan \rho\,;\ \text{then } \frac{\dot{a}}{\dot{c}} \text{ from } \bar{h}\textbf{\textit{ol}}.$$

Triclinic Elements. Signs of angles and functions must be considered.

oox $\cot \beta = \sin \varphi \tan \rho.$

okl $\cot \beta = \sin \varphi \tan \rho.$

hol $\cot \alpha = \sin (\varphi^{100} - \varphi) \tan \rho.$

100 $\cot \alpha = \sin (\varphi - \varphi^{001}) \tan \rho^{001}.$

$$\cos \gamma = \cos \varphi \sin \alpha \sin \beta - \cos \alpha \cos \beta$$

hko $a = \frac{h}{k}(\cot \mathrm{BCL} \sin \gamma + \cos \gamma)$ in which

$\mathrm{BCL} = \mathrm{BCZ} \pm \mathrm{LCZ}$; * $\cot \mathrm{BCZ} = \cot \varphi^{001} \cos \rho^{001}$

$\cot \mathrm{LCZ} = \cot (\varphi^{001} - \varphi) \cos \rho^{001}$

hk̄o $a = \frac{h}{k}(\cot \mathrm{BCL}' \sin \gamma - \cos \gamma)$ in which

BCL′ precisely analogous formulæ as for BCL

okl $\dot{c} = \frac{l}{k}[\sin (\varphi^{100} - \varphi) \tan \rho \sin \alpha + \cos \alpha]$

ok̄l $\dot{c} = \frac{l}{k}[\sin (\varphi^{100} - \varphi) \tan \rho \sin \alpha - \cos \alpha]$

hol $\frac{\dot{c}}{a} = \frac{l}{h}(\sin \varphi \tan \rho \sin \beta + \cos \beta)$

h̄ol $\frac{\dot{c}}{a} = \frac{l}{\bar{h}}(\sin \varphi \tan \rho \sin \beta - \cos \beta)$

hkl / ***hk̄l*** Substitute φ and ρ in formula under *hol.*

h̄kl / ***h̄k̄l*** Substitute φ and ρ in formula under *h̄ol.*

D. CALCULATION OF COÖRDINATE ANGLES IN TERMS OF CALCULATED ELEMENTS AND GRAPHICALLY DETERMINED INDICES.

The proof of the accuracy of the graphic determination of the indices requires the placing side by side of the calculated and the measured angles of each face. If then the differences are not in excess of two or three minutes for faces yielding fair reflections and

* As shown from the projection. Fig. 27.

say ten minutes for faces yielding very blurred images the indices may be assumed to be established.

Isometric Coördinate Angles* $h > k > l$.

For any form

$$\tan \varphi = \frac{\text{1st index}}{\text{2d index}}, \quad \cot \rho = \frac{\text{3d index}}{\text{2d index}} \cos \varphi, = \frac{\text{3d index}}{\text{1st index}} \sin \varphi.$$

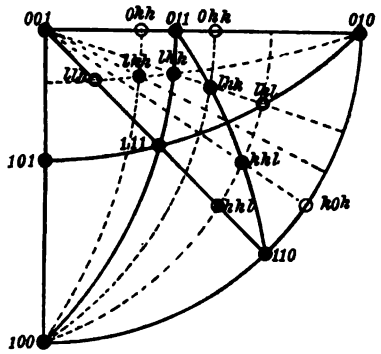


FIG. 22.

Isometric planes with $h = 3$, $k = 2$, $l = 1$.

Tetragonal Coördinate Angles.† $h > k$. l is index on c.

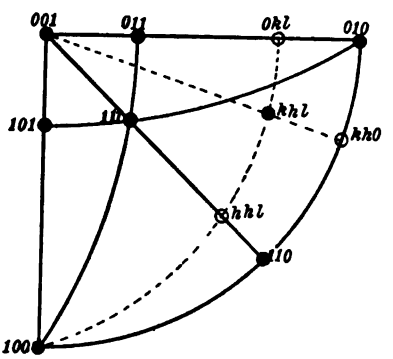


FIG. 23.

Tetragonal Planes on Zircon Elements and $h = 15$, $k = 5$, $l = 3$.

* The coördinate angles for all known isometric forms may be found under the various isometric minerals in Goldschmidt's "Winkeltabellen."

† ϕ is independent of axial elements, both in tetragonal and hexagonal. Values of ϕ for different indices are given in Goldschmidt's "Winkeltabellen," p. 25, where $p:q = \frac{h}{k}$.

kho*	$\cot\varphi = \frac{h}{k}$	$\rho = 90°$.
okl	$\varphi = 0°$	$\tan\rho = \dot{c}\frac{k}{l}$.
hhl	$\varphi = 45°$	$\tan\rho = 1.4142\frac{h\dot{c}}{l}$.
khl*	$\cot\varphi = \frac{h}{k}$	$\tan\rho = \frac{k}{l}\frac{\dot{c}}{\sin\varphi}$.

Hexagonal† Coördinate Angles. $h > k$. l is index on $\dot{c}$.

hkīo	$\tan\varphi = 1.732\frac{i-h}{i+h}$,	$\rho = 90°$.
hoh̄l	$\varphi = 0°$,	$\tan\rho = 1.1547\frac{h}{l}\dot{c}$.

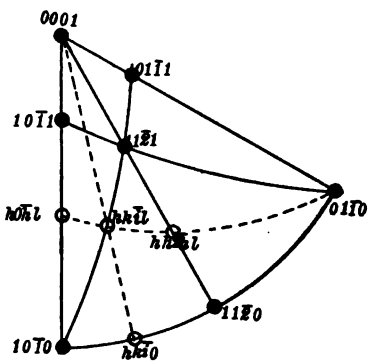


FIG. 24.

Hexagonal Planes on Beryl Elements and $h = 3$, $k = 1$, $l = 4$.

h·h·2̄h·l	$\varphi = 30°$	$\tan\rho = 2\frac{h}{l}\dot{c}$.
hkīl	$\tan\varphi = 1.732\frac{i-h}{i+h}$,	$\tan\rho = \frac{i}{l}\cdot\frac{\dot{c}}{\cos(30° - \varphi)}$.

Orthorhombic Coördinate Angles. h, k, l in order $\dot{a}, \bar{b}, \dot{c}$.

hko	$\cot\varphi = \dot{a}\frac{k}{h}$	$\rho = 90°$.
okl	$\varphi = 0°$	$\tan\rho = \dot{c}\frac{k}{l}$.

* Faces of forms {*hko*} {*hkl*}.

† For relation to angles in Goldschmidt's Winkeltabellen, see p. 22.

hol $\varphi = 90°$ $\tan \rho = \frac{\dot{c}}{\dot{a}} \frac{h}{l}$.

hkl $\cot \varphi = \dot{a} \frac{k}{h}$ $\tan \rho = \frac{k}{l} \frac{\dot{c}}{\cos \varphi}$.

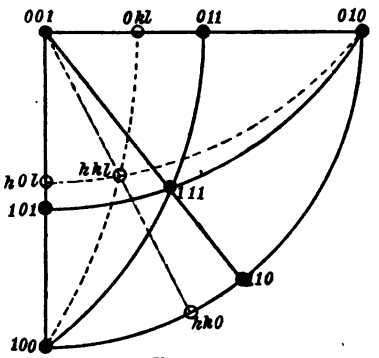


FIG. 25.

Orthorhombic Planes on Anglesite Elements, and $h = 3$, $k = 2$, $l = 4$.

Monoclinic Coördinate Angles. h, k, l in order $\dot{a}$, $\bar{b}$, $\dot{c}$.

oor $\varphi = 90°$ $\tan \rho = \sin \varphi^{okl} \tan \rho^{okl} = \cot \beta$

hko $\cot \varphi = \dot{a} \frac{k}{h} \sin \beta$ $\rho = 90°$

okl $\cot \varphi = \dot{c} \frac{k}{l} \tan \beta$ $\tan \rho = \frac{k}{l} \frac{\dot{c}}{\cos \varphi}$

hol $\varphi = 90°$ $\tan \rho = \frac{h}{l} \cdot \frac{\dot{c}}{\dot{a}} \cdot \frac{1}{\sin \beta} + \cot \beta$

$\bar{h}$ol $\varphi = \overline{90}°$ $\tan \rho = \frac{h}{l} \cdot \frac{\dot{c}}{\dot{a}} \frac{1}{\sin \beta} - \cot \beta$

hkl $\tan \varphi = \frac{h}{k\dot{a} \sin \beta} + \frac{l}{k\dot{c}} \cot \beta$ $\tan \rho = \frac{k}{l} \cdot \frac{\dot{c}}{\cos \varphi}$

$\bar{h}$kl $\tan \varphi = \frac{h}{k\dot{a} \sin \beta} - \frac{l}{k\dot{c}} \cot \beta$. $\tan \rho = \frac{k}{l} \frac{\dot{c}}{\cos \varphi}$.

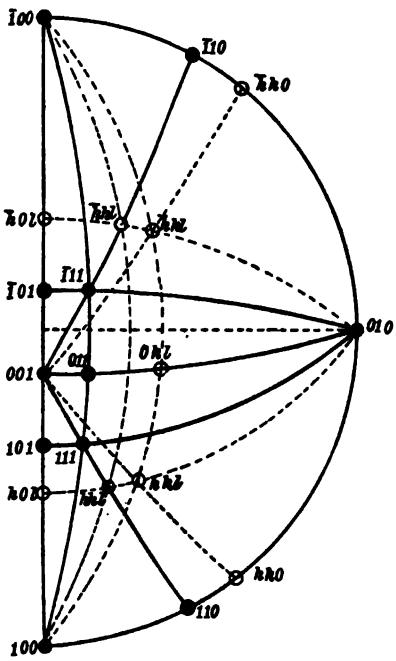


FIG. 26.

Monoclinic Planes on Amphibole Elements and $h=2$, $k=3$, $l=1$.

Triclinic Coördinate Angles. h, k, l in order a, b, c.

The known elements and indices with the addition of φ of 100 (the interfacial angle AB) yield the following:

oor $$\cot\varphi = \frac{\cot\alpha}{\sin\varphi^{100}\cot\beta} + \cot\varphi^{100};\quad \tan\rho = \frac{\cot\beta}{\sin\varphi}$$

hko $$\cot\varphi = \frac{k}{h}\cot\varphi^{110} + \frac{h-k}{h}\cot\varphi^{100},\quad \rho = 90°.$$

hk̄o $$\cot\varphi = \frac{k}{h}\cot\varphi^{1\bar{1}0} - \frac{h-k}{h}\cot\varphi^{100},\quad \rho = 90°.$$

okl $$\cot\varphi = \frac{\frac{k}{l}c - \cos\alpha}{\sin\alpha\cot\beta\sin\varphi^{100}} + \cot\varphi^{100};\quad \tan\rho = \frac{\cot\beta}{\sin\varphi}.$$

ok̄l $$\cot\varphi = \frac{\frac{k}{l}c + \cos\alpha}{\sin\alpha\cot\beta\sin\varphi^{100}} + \cot\varphi^{100};\quad \tan\rho = \frac{\cot\beta}{\sin\varphi}.$$

hol, $$\cot\varphi = \frac{\cot\alpha\sin\beta}{\left(\frac{h}{l}\cdot\frac{c}{a} - \cos\beta\right)\sin\varphi^{100}} + \cot\varphi^{100};\quad \tan\rho = \frac{\cot\alpha}{\sin(\varphi^{100}-\varphi)}$$

$$\bar{h}ol,\ \cot\varphi = \frac{\cot\alpha\sin\beta}{\left(\frac{h}{l}\cdot\frac{c}{a}+\cos\beta\right)\sin\varphi^{100}} + \cot\varphi^{100};$$

$$\tan\rho = \frac{\cot\alpha}{\sin(\varphi^{100}-\varphi)}$$

$$hkl,\ \cot\varphi = \frac{\left(\frac{k}{l}c-\cos\alpha\right)\sin\beta}{\left(\frac{h}{l}\cdot\frac{c}{a}-\cos\beta\right)\sin\alpha\sin\varphi^{100}} + \cot\varphi^{100};$$

$$\tan\rho = \frac{\frac{h}{l}\cdot\frac{c}{a}-\cos\beta}{\sin\varphi\sin\beta}$$

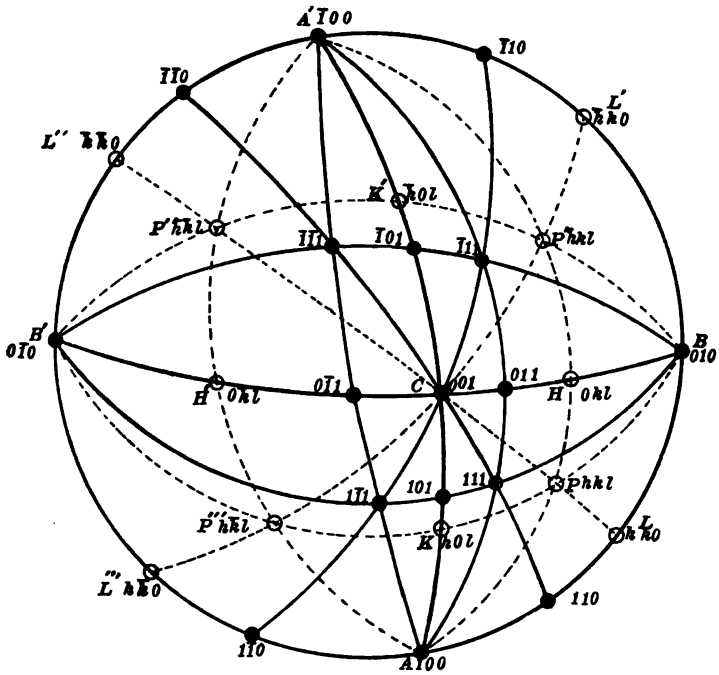


FIG. 27.

Triclinic Planes on Chalcanthite Elements and $h=3$, $k=6$, $l=2$.

$$\bar{h}kl,\ \cot\varphi = \frac{\left(\frac{k}{l}c-\cos\alpha\right)\sin\beta}{\left(\frac{h}{l}\cdot\frac{c}{a}+\cos\beta\right)\sin\alpha\sin\varphi^{100}} + \cot\varphi^{100};$$

$$\tan\rho = \frac{\frac{h}{l}\cdot\frac{c}{a}+\cos\beta}{\sin\varphi\sin\beta}$$

$$\boldsymbol{h\bar{k}l}, \cot\varphi = \frac{\left(\frac{k}{l}c + \cos a\right)\sin\beta}{\left(\frac{h}{l}\cdot\frac{c}{a} - \cos\beta\right)\sin a \sin\varphi^{100}} - \cot\varphi^{100};$$

$$\tan\rho = \frac{\frac{h}{l}\cdot\frac{c}{a} - \cos\beta}{\sin\varphi\sin\beta}$$

$$\boldsymbol{\bar{h}\bar{k}l}, \cot\varphi = \frac{\left(\frac{k}{l}c + \cos a\right)\sin\beta}{\left(\frac{h}{l}\cdot\frac{c}{a} + \cos\beta\right)\sin a \sin\varphi^{100}} - \cot\varphi^{100};$$

$$\tan\rho = \frac{\frac{h}{l}\cdot\frac{c}{a} + \cos\beta}{\sin\varphi\sin\beta}$$

E. TRANSFORMATIONS.

It will frequently happen that the first orientation chosen is not the one finally adopted.

Transformation to any New Polar Plane and New Meridian.

In Fig. 28 let C and C' be respectively old and new polar planes;

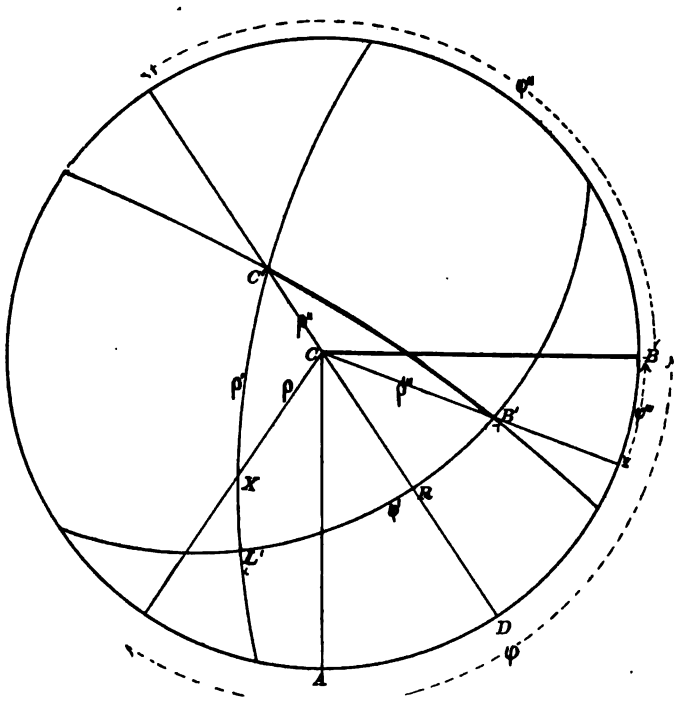


FIG. 28.

CB and $C'B'$, old and new prime meridians and X any face. Let $\varphi\rho$, $\varphi''\rho''$ and $\varphi'''\rho'''$ be the coördinates respectively of X, C' and B' referred to the old origins and $\varphi'\rho'$ the *new* coordinates of X.

Then * $\cos \rho' = \cos \rho \cos \rho'' + \sin \rho \sin \rho'' \cos (\varphi - \varphi'')$.

And $\cos \varphi' = \dfrac{\cos \rho \cos \rho''' + \sin \rho \sin \rho''' \cos (\varphi''' - \varphi)}{\sin \rho'}$.

Special cases.

New pole at B. $\cos \rho' = \cos \varphi \sin \rho$ · $(\varphi'' = 0° ; \rho'' = 90°)$.

New pole at A. $\cos \rho' = \sin \varphi \sin \rho$ $(\varphi'' = 90° ; \rho'' = 90°)$.

New meridian at C. $\cos \varphi' = \dfrac{\cos \rho}{\sin \rho'}$ $(\varphi''' = 0° ; \rho''' = 0°)$.

New meridian at A. $\cos \varphi' = \dfrac{\sin \rho \sin \varphi}{\sin \rho'}$ $(\varphi''' = 90° ; \rho''' = 90°)$.

New meridian at B. $\cos \varphi' = \dfrac{\sin \rho \cos \varphi}{\sin \rho'}$ $(\varphi''' = 0° ; \rho''' = 90°)$.

Graphic Check on Transformation.

With the aid of protractor II. we may find the new coördinate angles φ' and ρ', for each face graphically, thus checking the above calculation.

Draw diameter $C'CD$ through new pole C', Fig. 28. Locate R on this diameter so that $RD = CC'$ (in stereographic degrees by protractor No. I.), thus making $C'R = 90°$. Draw a great circle through R and B', the new meridian face. Then the new coördinate angles φ' and ρ' are easily found, φ' being measured on $B'R$ (the new equatorial), by protractor No. II., and ρ' on the great circle through C' and the given face by the same protractor.

Transformations by Means of Indices.

From the original indices of the planes which in the new orientation are to be (010), (001), (100), determine the symbols of their intersections (that is, their zone-symbols),

$$[uvw],\ [u_1v_1w_1],\ [u_2v_2w_2.]$$

Then, if the symbol of any face referred to the old axes is hkl, its new indices h_1, k_1, l_1, will have the following values.†

---

* In $CC'X$ know two sides and included angle.
In $B'CX$, $\cos B'X = \cos \rho \cos \rho''' + \sin \rho \sin \rho''' \cos (\phi''' - \phi)$.
In $B'C'X$, $B'C' = 90°$; $B'C'X = \phi$.

† Miller. *Teratise on Crystallography*, p. 17.

$$h_1 = hu + hv + hw.$$
$$k_1 = ku_1 + kv_1 + kw_1.$$
$$l_1 = lu_2 + lv_2 + lw_2.$$

F. TWINNED CRYSTALS.

Poles of corresponding faces on twinned individuals will be equally distant from the pole of the twinning plane. The zones connecting pairs of such poles will intersect in the pole of the twinning plane. Graphically therefore protractor No. II. will often reveal the twinning plane.

If φ^τ and ρ^τ are the coördinate angles of the twinning plane and $\varphi, \rho, \bar{\varphi}, \bar{\rho}$, the coördinate angles of corresponding faces of the two indivduals then

$$\tan \varphi^\tau = \frac{\sin \varphi + M \sin \bar{\varphi}}{\cos \varphi + M \cos \bar{\varphi}} \text{ in which } M = \frac{\sin \bar{\rho}}{\sin \rho}.$$

$$\tan \rho^\tau = \frac{\cos \rho - \cos \rho}{R \sin \rho - S \sin \bar{\rho}} \text{ in which}$$

$$R = \cos (\varphi^\tau - \varphi) ; \; S = \cos (\bar{\varphi} - \varphi^\tau).$$

V. OBTAINING COÖRDINATE ANGLES FROM INTERFACIAL ANGLES.

One Circle Measurement.

In spite of the great advantages of the two-circle goniometer, it is sometimes more convenient to determine the morphology of crystals by interfacial angles obtained from the one-circle goniometer. The usual methods of one-circle measurement, involving a readjustment for each zone, and the calculations for indices, elements, and angles by the solution of spherical triangles and by special ormulæ are given in most books on crystallography.

For record and comparison the coördinate angles are more useful than the interfacial, and in many cases it would seem advisable to transform the interfacial angles to the coördinate by means of the formulæ following and to use the coördinate angles so obtained in the calculation.*

As a check on the transformation the one-circle measurements may be plotted and the coördinate angles graphically determined.

* Unless exact results are required the graphically determined coördinate angles suffice.

Projection from Interfacial Angles.

Angles in the prismatic zone are laid off in their true value on the equatorial. Angles in vertical zones are laid off with protractor I. The zone-circles connecting poles of faces of these zones will contain most of the other planes. Angles of these zones may be laid off by protractor I. or by the usual method.*

In general the projection of any face *hkl* is determined by the angles it makes with the projection of two known faces. The pole of the desired face lies at the intersection of two circles. A radius is drawn through the pole of the known face and the distance in stereographic degrees from the required face is laid off on each side of the pole with scale No. 3.† A circle (or arc) with its center midway between the extreme points and with a radius equal to the distance of one point to the center gives the locus of all poles which are at the required distance from the desired face. Similarly another circle is drawn about the other known pole. The intersection of the two arcs will give the desired pole. In general there will be two intersections. To decide which is the proper one is generally easy from an inspection of the crystal.

If the known pole is on the equatorial it is more convenient to find the radius of circle (which is now a small vertical circle) from scale No. 2. The center of the circle is on the prolonged radius through the known pole. One point of the circumference of the circle is on the divided circle equal to the desired angular distance from the known pole. With the radius determined from scale No 2 the center of the circle is found.

In triclinic projections the angles α, β and $AB(100:010)$, Fig. 27, fix the position of the three pinacoids and the zone circles through them. α and β are measured on radii 90° from A and B respectively by protractor No. I., Fig. 21. Prisms are laid off directly on the equatorial. Domes are located on the zone circles BC and AC by scale No. 2 as just described.

Isometric System. $h > k > l$. See Fig. 22.

For any face pqr.

$$\rho = \tfrac{1}{2}(pqr : \bar{p}\bar{q}r) = 90° - \tfrac{1}{2}(pqr - p\bar{q}r).$$

* Moses, "Characters of Crystals," p. 22.

† On sheets described by Prof. Penfield, *l. c.*

For the faces lkh, lhh, khk

$$\cot\varphi = 1 + \sqrt{2}\cdot\frac{\sin X}{\sin Y} \qquad \sin\rho = \frac{\sin Y}{\sin\varphi}$$

$$\frac{X}{Y} = \frac{\frac{1}{2}(lkh : klh)}{\frac{1}{2}(lkh : \bar{l}kh)} \text{ or } \frac{\frac{1}{2}(llh : hlh)}{\frac{1}{2}(lhh : \bar{l}hh)} \text{ or } \frac{\frac{1}{2}(khk : hkk)}{\frac{1}{2}(khk : \bar{k}hk)}.$$

Tetragonal System. $h > k$. See Fig. 23.

For any face pqr.

$$\rho = \tfrac{1}{2}(pqr : \bar{p}qr) = 90° - \tfrac{1}{2}(pqr : pq\bar{r}).$$

kho $\varphi = \tfrac{1}{2}(kho : \bar{k}ho) \qquad \rho = 90°$

$= 45° - \tfrac{1}{2}(kho : hko)$

hhl $\varphi = 45° \qquad \sin\rho = \sqrt{2}\cdot\sin\tfrac{1}{2}(hhl : \bar{h}hl).$

$= \sqrt{2}\cdot\cos(hhl : 010).$

khl $\cot\varphi = 1 + \sqrt{2}\dfrac{\sin\frac{1}{2}(khl : hkl)}{\sin\frac{1}{2}(khl : \bar{k}hl)} \qquad \sin\rho = \dfrac{\sin\frac{1}{2}(khl : \bar{k}hl)}{\sin\varphi}.$

$\tan\varphi = 1 - \sqrt{2}\dfrac{\sin\frac{1}{2}(khl : hkl)}{\cos(khl : 010)} \qquad = \dfrac{\cos(khl : 010)}{\cos\varphi}.$

$= \dfrac{\sin\frac{1}{2}(khl : hkl)}{\sin(45° - \varphi)}.$

$= \sqrt{2}\cdot\sin\tfrac{1}{2}(khl : h\bar{k}l).$

Hexagonal System. $h > k$, $h + k = i$. See Fig 24.

hkīo $\varphi = 30° - \tfrac{1}{2}(hk\bar{i}o : kh\bar{i}o) \qquad \rho = 90°.$

$= \tfrac{1}{2}(hk\bar{i}o : i\bar{k}ho)$

hohl $\varphi = 0° \qquad \sin\rho = 2\sin\tfrac{1}{2}(oh\bar{h}l : oh\bar{h}\bar{l})$

$= 1.1547\sin\tfrac{1}{2}(hoh\bar{l} : \bar{h}hol).$

hhīhl $\varphi = 30° \qquad \sin\rho = 2\sin\tfrac{1}{2}(hh\bar{i}hl : h\bar{i}hh\bar{l})$

hkīl $\cot\varphi = 1.732 + \dfrac{2\sin V}{\sin S} \qquad \sin\rho = \dfrac{\sin S}{\sin\varphi}.$

$= 0.5773 + \dfrac{1.1547\sin R}{\sin S} \qquad = \dfrac{\sin V}{\sin(30° - \varphi)}.$

$$\tan\varphi = \frac{2\cos T}{\cos(hk\bar{i}l \cdot 10\bar{1}0)} - 1.732 \qquad \sin\rho = \frac{\sin R}{\sin(60° - \varphi)} = \frac{\cos T}{\cos(30° - \varphi)} = \frac{\cos(hk\bar{i}l : 10\bar{1}0)}{\cos\varphi}$$

$R = \frac{1}{2}(hk\bar{i}l : \bar{h}i\bar{k}l)$, $S = \frac{1}{2}(hk\bar{i}l : i\bar{k}\bar{h}l)$, $T = \frac{1}{2}(hkil : kh\bar{i}\bar{l})$

$V = \frac{1}{2}(hkil : kh\bar{i}l)$ $\cos T = \sin R + \sin S$.

Orthorhombic System. See Fig. 25.

hko	$\varphi = \frac{1}{2}(hko : \bar{h}ko) = 90° - \frac{1}{2}(hko : h\bar{k}o)$	$\rho = 90°$
okl	$\varphi = 0°$	$\rho = \frac{1}{2}(okl : ok\bar{l})$
hol	$\varphi = 90°$	$\rho = \frac{1}{2}(hol : \bar{h}ol)$
hkl	$\tan\varphi = \frac{\sin\frac{1}{2}(hkl : \bar{h}kl)}{\sin\frac{1}{2}(hkl : h\bar{k}l)} = \frac{\cos(hkl : 100)}{\cos(hkl : 010)}$	$\rho = \frac{1}{2}(hkl : \bar{h}\bar{k}l)$, $\sin\rho = \frac{\sin\frac{1}{2}(hkl : \bar{h}kl)}{\sin\varphi} = \frac{\sin\frac{1}{2}(hkl : h\bar{k}l)}{\cos\varphi} = \frac{\cos(hkl : 100)}{\sin\varphi} = \frac{\cos(hkl : 010)}{\cos\varphi}$

Monoclinic System. See Fig. 26. $\beta = (001 : 100)$.

hko	$\varphi = \frac{1}{2}(hko : \bar{h}ko)$	$\rho = 90°$
okl	$\sin\varphi = \cot\rho\cot\beta$	$\cos\rho = \cos\frac{1}{2}(okl : ok\bar{l})\sin\beta = \cos(okl : 100)\tan\beta$
hol	$\varphi = 90°$	$\rho = 90° - (hol : 100)$
$\bar{h}ol$	$\varphi = 90°$	$\rho = 90° - (\bar{h}ol : \bar{1}00)$
hkl	$\tan\varphi = \frac{\cos(hkl : 100)}{\cos(hkl : 010)}$,	$\sin\rho = \frac{\cos(hkl : 010)}{\cos\varphi} = \frac{\cos(hkl : 100)}{\sin\varphi}$.

$\bar{h}kl$ $\quad \tan\varphi = \dfrac{\cos(\bar{h}kl : \bar{1}00)}{\cos(\bar{h}kl : 010)}, \quad \sin\rho = \dfrac{\cos(\bar{h}kl : 010)}{\cos\varphi} = \dfrac{\cos(\bar{h}kl : \bar{1}00)}{\sin\varphi}.$

Triclinic System. See Fig. 27. $\frac{1}{2}S = \frac{1}{2}(AB + BC + AC)$.

$$\cot\frac{\alpha}{2} = \sqrt{\frac{\sin(\frac{1}{2}S - AC)\sin(\frac{1}{2}S - AB)}{\sin\frac{1}{2}S\sin(\frac{1}{2}S - BC)}},$$

$$\cot\frac{\beta}{2} = \cot\frac{\alpha}{2}\cdot\frac{\sin(\frac{1}{2}S - BC)}{\sin(\frac{1}{2}S - AC)},$$

$$\cot\frac{\gamma}{2} = \cot\frac{\alpha}{2}\cdot\frac{\sin(\frac{1}{2}S - BC)}{\sin(\frac{1}{2}S - AB)},$$

$00l(C)$ $\quad \cot\varphi = \dfrac{\cot BC}{\cos\beta}, \quad \sin\rho = \dfrac{\cos BC}{\cos\varphi},$

$$\cos\rho = \sin\alpha\sin AC,$$

$0kl(H)$ $\quad \cot\varphi = \dfrac{\cot BH}{\cos\beta}, \quad \sin\rho = \dfrac{\cos BH}{\cos\varphi} = \dfrac{\cos AH}{\cos(\varphi^{100} - \varphi)}.$

$0\bar{k}l(H')$ Substitute H' for H in above formulæ.

$h0l(K)$ $\quad \cos\varphi = \dfrac{\cos BK}{\sin\rho}, \qquad \cos\rho = \sin\alpha\sin AK.$

$\bar{h}0l(K')$ Substitute K' for K in above formulæ.

$hkl(P)$ $\quad \tan\varphi = \dfrac{\cos AP}{\cos BP\sin AB} - \cot AB, \quad \sin\rho = \dfrac{\cos AP}{\cos(AB - \varphi)} = \dfrac{\cos BP}{\cos\varphi} = \dfrac{\cos LP}{\cos(BL - \varphi)}.$

$\bar{h}kl(P')$ Substitute A', P', and L' for A, P, and L in above.

$\bar{h}\bar{k}l(P'')$ Substitute A', B', P'', and L'' for A, B, P, and L in above.

$h\bar{k}l(P''')$ Substitute B', P''', and L''' for B, P, and L in above.

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK, June, 1902.

SOME NEW WORK ON PROPERTIES OF EXPLOSIVE MIXTURES.

By CHARLES E. LUCKE, M.S., Ph.D.
Mechanical Engineering Department.

The Apparatus.

All work in the experimental study of heat is, as is well known, very difficult, calling for most careful observations with apparatus sometimes impossible to construct with sufficient accuracy, and always expensive even to a slight degree of accuracy. The study of the characteristics of explosive mixtures is no exception to the rule, partaking of the general difficulty of all heat work, that of isolation of phenomena of observation, and the prevention of the manifestation of more than one at a time. In most cases each experimenter has designed and constructed apparatus of his own, and in no case, it seems, has any one used instruments first employed by a predecessor. It is probably due to this that the results of different observers do not always agree. In none of the researches does there seem to have been adopted a sufficiently direct and simple means for obtaining ALL the results; having an instrument to measure one constant the observer has rested content with COMPUTING others equally important, which were mathematically related, though these computed values might also have been observed directly. As actual trial has shown that the results obtained by this process of computation of constants from observed values of some other related constant is not always reliable, introducing, as it generally does, a multiplied error *if not involving unproved assumptions of interrelation,* it seemed desirable, (1), that each constant needed be measured directly under well-defined conditions, and (2), that the apparatus for the measurements be made simple enough for duplication by others whose observations could act as a check on the results. In this reduction to simplicity it is essential that the apparatus be so constructed as to permit of measurements on the mixtures under as nearly the same conditions as found in engineering practice as was possible. Such a set of apparatus once set up in a laboratory can be used to rapidly determine what is wanted from time to time as occasion might demand, and the results could easily be checked up by other ob-

servers on the same or duplicated apparatus. The actual construction should involve little or no machine work, and the instruments of observation must be those in common use in the general engineering laboratory.

The results of the work on continuous explosive combustion of gaseous mixtures furnished a ready means for obtaining burnt gases for dilution of mixtures of otherwise known composition of air and gas. The action and appearance of the fire itself furnishes a very good and simple means for determining the propor-

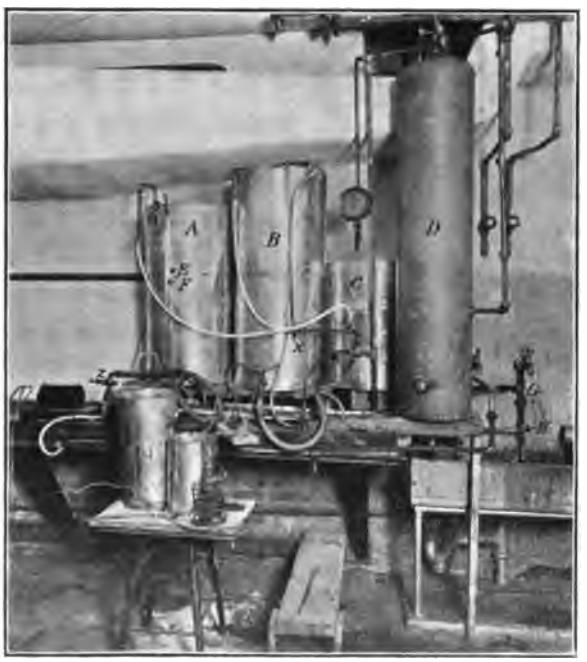


FIG. 1.

tions being fed, and hence the character of the products of combustion, whether oxidizing reducing or neutral, within limits pretty close; much closer than we can attain to constancy in gas-engine work.

For a constant pressure combustion-calorimeter this same method also filled requirements. For, as has been shown, a mixture of air, gas and neutral in any proportions that can be exploded may be burnt in a closed chamber and under pressure, so there

only remains as a necessity, the provision for measuring gas burnt and heat developed by submerging the whole apparatus in water. The details of this calorimeter as adopted and used will be noted later.

Gas measuring, mixing and storing was accomplished by water displacement in thin metal tanks; the quantities read by the levels in a water glass before and after more water had displaced the gas required. All connections and communications between the parts were made of combinations of pipe fittings and rubber hose. Four tanks were provided. (Fig. 1, *A, B, C, D*), each fitted with water inlet and discharge communicating with water main and sewer, and each fitted also with gas inlet communicating with the appropriate source and discharges connecting *A, B,* and *C* with *D* and that of *D* with the apparatus in which mixtures were to be used. The first three tanks then were measuring tanks, *A,* for illuminating gas, *B,* for air, and *C* for products of combustion prepared previously, while the fourth, *D,* is the mixing and storage tank and is the only one in which the pressure was allowed to exceed atmosphere. Two glass tubes, *E* and *F,* were provided to each of the measuring tanks and extending the entire length. One of these tubes, *F,* was connected by both ends to the interior, while the other, *E,* was connected at the bottom, only the top being open to atmosphere, Fig. 2. The doubly connected tube then serves as an ordinary water column showing the water level, while the other gives an indication of the interior pressure. When the level of the open column is equal to that in the closed column the pressure on the interior is atmosphere; if the level of the open column rises above that of the closed column then the interior pressure exceeds atmosphere by an amount exactly equal to that due to difference of level.

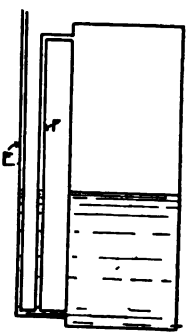


FIG. 2.

To obtain a mixture of any composition the method of operation was as follows: All tanks were filled with water till they overflowed; then, one at a time, the water was allowed to flow out of the measuring tanks *A, B, C* and illuminating gas, air and products of combustion, flowing in each to its own tank, filled the

space left by the receding water. Manipulation of the gas discharge and water inlet valves, guided by the relative position of the water levels in the two columns, enabled the operator to keep the pressure on the inside equal to atmosphere, and relieving the walls of any stress as well as preventing compression or rarefication of the gas. When each tank is filled with its respective gas the amounts of each desired in the mixture are laid off on the water glass above the present water level and, as these have all the same diameter, the height on the columns will be a measure of the quantity of the gas. Water is then turned out of the storage tank *D* and a partial vacuum created therein. With one hand on the gas cock *x* and the other on the water cock *y*, the amount of gas wanted is caused to flow from tank *A*, where it was measured, to the tank *D*, where it is wanted, the transfer being made without allowing any change of pressure in tank *A* by simply regulating the relative openings of the valves *x* and *y* and watching the two water columns. After the gas wanted is transferred air is similarly measured and transferred, and later, if desired, products of combustion, until finally the tank *D* contains all the constituents of the desired mixture. All openings to *D* are then closed and water from the main *G* admitted through the three-way cock *H*, until the full pressure (in this case 60 lbs. gauge) has compressed the mixture. This method of feeding and afterward compressing, results in a perfectly uniform mixture, as was proved by comparing effects derived from burning parts first drawn off with the last that remained.

We have now in tank *D* a perfectly uniform mixture of known composition, compressed to 60 lbs. and available for whatever tests or experiments we may desire to make, by the simple opening of the valve *J*. All this measuring, transferring and compressing the constituents of the mixture takes about five minutes from the beginning up to the time the mixture is ready for use. When the operator is working with one mixture this time may be lessened if an assistant is at hand to recharge measuring tanks and get the quantities desired measured off for the next mixture desired.

Neutral Gas Generator.

To generate neutral products of combustion a positive blower *A*, Fig. 3, driven by a Crocker-Wheeler motor *B*, fed an ex-

plosive mixture of air and gas to the two-inch tee *C*. The proportions were obtained as desired by air-cock *D* and gas-cock *E* on the blower suction and the mixture thus obtained burned within the mass of broken magnesite in the tee *C*. Ignition was effected through the opening *G*, and when the proportions were found correct by observing the fire this opening was closed, thus sending the products of combustion over through pipe *J* to bell *K* under

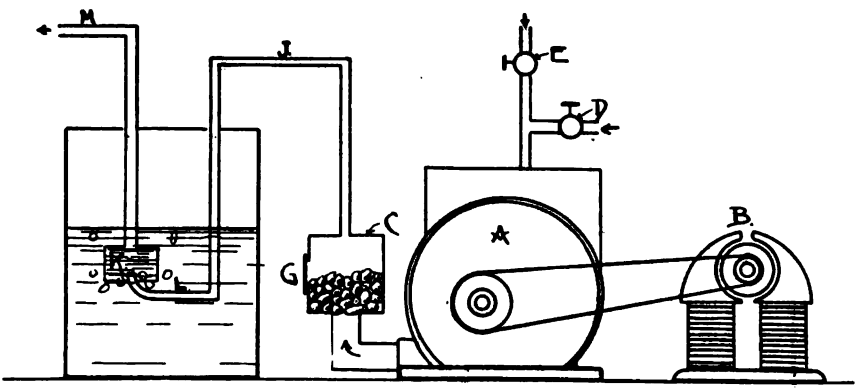


FIG. 3.

water in tank *L*. When wanted the products of combustion could be drawn off from *K* through pipe *M* under a constant pressure, being that due to the height of water above the bell. More gases than were wanted were continuously generated, the surplus always bubbling off from bell *K;* this was to insure getting fresh gases delivered at constant and small head. The water around the pipes served to condense and catch any steam in the products.

CONSTANT PRESSURE COMBUSTION GAS CALORIMETER.

The constant pressure calorimeter consisted of a one-half-inch tee *F*, Fig. 4, nearly full of broken magnesite and fitted with a jump-spark plug *G* operated by a vibratory primary circuit breaker induction coil. Explosive mixtures of the previously determined composition and of known amount were fed to the bottom of the combustion chamber *F* through a one-eighth-inch copper tube *E*. As it was necessary to discharge the whole of the measured quantity of mixture from the pressure tank *D*, and necessary secondly that no water should follow, the trap *B* was introduced.

It is simply a glass bottle with two glass tubes, one a feed and the other discharge, fitted to a perforated cork. The discharge tube was connected with the calorimeter by the light rubber tube *D*. Hot gases from *F* were discharged through *H* to the bottom of the water tank and thence passed up through square coil of one-

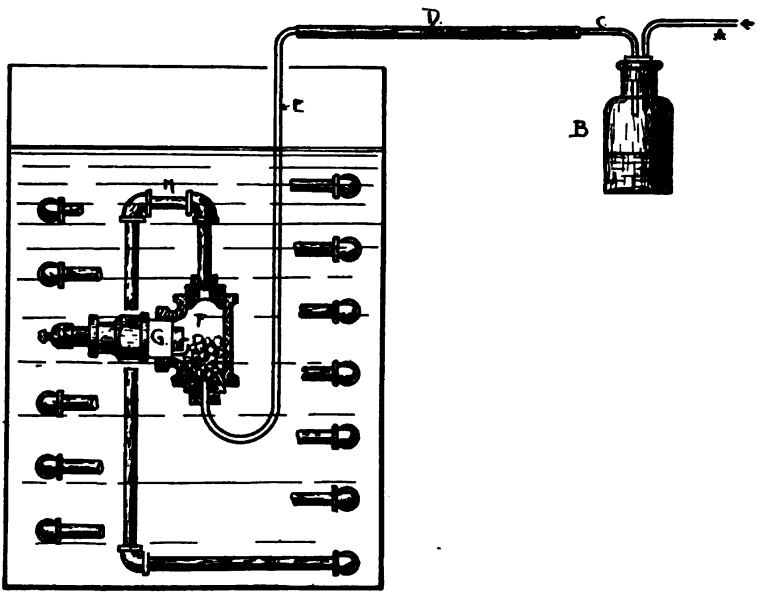


FIG. 4.

eighth-inch iron pipe. The end of this coil was supplied with rubber and glass tubes, so that the products of combustion could be directed to the atmosphere or to any point of the water to act as a stirrer when so desired.

CONSTANT VOLUME COMBUSTION PRESSURE RATIO CHAMBER.

The explosion chamber for determining the pressures due to constant volume combustion consisted primarily of tee *A*, Fig. 5, nipples *B* and caps *C*, *C'*. A Crosby gas-engine indicator was attached to the tee as shown. The spark plug *D* was carried in one branch of the three-way cock on top and on other branch was connected to mixture feed and water overflow openings *E*. The apparatus was first filled with water through valve *F* until it overflowed through valve *G*, the mixture feeding valve *H* and

water discharge valve *J* being closed; the spark points meantime being protected from the water by the three-way cock. When entirely full of water valves *G* and *F* are closed and *H* and *J* opened, the mixture from tank *D* thus expelling the water; the three-way cock is then thrown to permit contact of points with

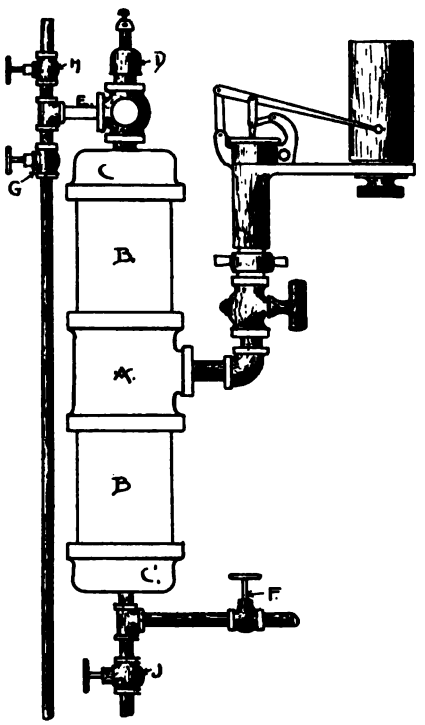


FIG. 5.

mixture, which is allowed to blow through freely to fill chamber at atmospheric pressure. Then all openings are closed and the mixture fired, the pressure rise being shown by the length of line drawn on the indicator drum to the proper scale. To expel the burnt gases water is admitted as before and the new charge subsequently used to drive the water out.

CONSTANT PRESSURE COMBUSTION VOLUME RATIO APPARATUS.

The quantity of gas that could be stored in the tank *D* is so small and the time to attain maximum effect in a heating chamber

so long, that with these tanks the combustion chamber could not become heated sufficiently to make a measurement of maximum volume increase. The apparatus of Fig. 6 was constructed with this end in view. It depends for its action on the principles of gas flow through an orifice. The rate of flow of a gas through an orifice is proportional to the form of orifice and to the pressure drop through the orifice. Now if the gas be caused to pass through a hole in a plate before combustion, and later, after combustion, pass through a similar hole in a similar plate, the constant due to the form of orifice would be eliminated in comparing velocities through the two holes. Secondly, when the fall in pressure through each hole is the same the velocity of flow through each plate will be equal, and the volume passing will be propor-

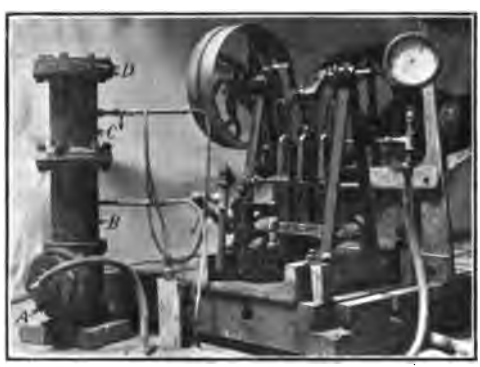


FIG. 6.

tional to the area of the orifice only if the pressures used be small enough to make correction for compression vanishingly small. Gas and air are mixed in any proportion desired at the compressor intake and delivered, mixed, to the chamber *AB*, from which the mixture will pass to the upper chamber *C* through a hole in the plate secured between the flanges. In chamber *C* there is placed a cone of brick to keep lower plate cool, and in the cone broken rock to permit of the combustion of the explosive mixture. The top plate between the flange *D* is provided with asbestos sheets to keep the hot gases from chilling just before issuing.

At times both the brick cone for the lower and the asbestos sheet protection for the upper plates were removed for the taking of

observations, while at another time a one-inch lining of fire clay was supplied to prevent radiation. Mercury manometers to both chambers indicate the interior pressures, and hence the drop in pressure through each plate.

RESULTS OBTAINED WITH APPARATUS. FLAMES IN ATMOSPHERE OF DIFFERENT AIR-GAS MIXTURES.

Before proceeding to the effects of the combustion of different mixtures it is necessary to first determine the limits of combustibility, and in so doing opportunity was afforded to observe the characteristics of the flames of different mixtures.

The mixture from the compression storage tank *D* was led to the apparatus, Fig. 7. This consisted of a one-quarter-inch tee with a valve *A* and manometer *B*, the flame locating at *C*. Mixtures were ignited and the flow regulated to determine the maximum length and character of the flame and the pressure at which the flame would blow off.

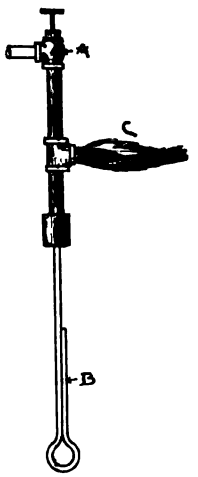


FIG. 7.

Appearance and blow-off pressures of mixtures of air and gas burnt at opening of one-quarter-inch pipe in atmosphere of air:

Mixture, { Air . . . 1 / Gas . . . 1 }

Blow-off pressure, 1.25″ H_2O

With a length of one-half inch a clear blue flame results; an increase to three inches in length develops a green core and faint spots of yellow appear. A still further increase of the pressure causes the core to become less distinct and the end of the flame becomes wavy and oscillatory. A roaring noise develops also. Just before blow-off the flame becomes violet and green near nozzle; the end is quite wide and spreading. Blow-off occurred at 1.25 inches of water pressure with a length of fourteen inches after some trembling at the nozzle.

Mixture, { Air . . . 2 / Gas . . . 1 } Blow-off pressure, .8″ H_2O.

Flame all blue and remained blue as length was increased with

A length of twelve inches was the maximum at a water pressure of eight-tenths of an inch.

$$\text{Mixture, } \left\{ \begin{matrix} \text{Air} & . & . & . & 3 \\ \text{Gas} & . & . & . & 1 \end{matrix} \right\} \text{ Blow-off pressure, .5" } H_2O.$$

First appearance of the flame cap, which was of yellowish color surrounded by light blue and could be extended to a maximum length of six inches with a blow-off pressure of one-half inch water. The cap, however, instead of being smooth, had serrated edges.

$$\text{Mixture, } \left\{ \begin{matrix} \text{Air} & . & . & . & 4 \\ \text{Gas} & . & . & . & 1 \end{matrix} \right\} \text{ Blow-off pressure, .3" } H_2O.$$

The flame cap is now more distinct, with a filmy halo surrounding it, color blue-green. The flame on extension becomes sharply pointed at the end with little vibration. At the maximum length of four inches and blow-off pressure of three-tenths of an inch the flame became very pale.

$$\text{Mixture, } \left\{ \begin{matrix} \text{Air} & . & . & . & 5 \\ \text{Gas} & . & . & . & 1 \end{matrix} \right\} \text{ Blow-off pressure, .12" } H_2O.$$

The flame was very similar in appearance to the last with the exception of being more blue than green, the tip was very pale and sharp-pointed at the maximum length of three and one-half inches.

$$\text{Mixture, } \left\{ \begin{matrix} \text{Air} & . & . & . & 6 \\ \text{Gas} & . & . & . & 1 \end{matrix} \right\} \text{ Blow-off pressure, .08" } H_2O.$$

Flame was somewhat shorter and somewhat more filmy or cloudy in character, the maximum length of a little more than two inches was reached with a water pressure of about eight one-hundredths of an inch.

Mixtures containing more air than the last could not be burnt.

The limits of explosive combustibility differ from the preceding limits for flames. When admitted to the explosion chamber, isolated and exploded in bulk the limits of combustibility were:

$$\left\{ \begin{matrix} \text{Air} & . & . & . & 3 \\ \text{Gas} & . & . & . & 1 \end{matrix} \right\} \text{ up to } \left\{ \begin{matrix} \text{Air} & . & . & . & 7. \\ \text{Gas} & . & . & . & 1. \end{matrix} \right.$$

But with the mixtures 6.5/1 up to 7/1 the ignition was very uncertain, occurring only after long passage of the spark and often failing entirely. This is an unfailing characteristic of

very much less spreading at the ends. There appeared no core. extremely dilute mixtures, *i. e.*, mixtures containing a large percentage of neutral or excess gases.

Constant Pressure Combustion Calorimeter.

Before stating the results of this calorimeter on an unanalyzed water gas it will be well to look at some characteristics of a water of typical composition. It is intended that this calorimeter be used by men unskilled in gas analysis and in places where such an apparatus is unavailable. The results that theoretically should accrue from this typical water gas will be compressed until what was actually observed on the action of the gas used.

Stillman gives as an ordinary water gas the following mixture:

CO_2	3.8
C_2H_4	14.6
CO	28.0
H	35.6
CH_4	16.7
N	1.3
Total	100.0

of this we have

NEUTRAL.

CO_2	3.8
N	1.3
Total	5.1

This gas, moreover, will heat yield 691.59 B. T. U. per cubic foot products condensed, and will call for in its combustion 5.21 parts of air per one part of gas.

A *chemical mixture* then would have these characteristics:

Air	5.21	volumes
Gas	1.00	"
Total	6.21	"

of which we have

Neutral { Neutral in gas .051
Nitrogen in air 4.120

Total neutral 4.17 in 6.21 parts or 67 per cent. neutral.

Let us then tabulate various mixtures and note some of their characteristics.

Gas.	1	1	1	1	1	1	1	1	1
Air.	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
Inactive Air, *i. e.*, Excess.						.29	.79	1.29	1.79
Active Air.	3.0	3.5	4.0	4.5	5.0	5.21	5.21	5.21	5.21
Inactive Gas, *i. e.*, Excess.	.427	.328	.232	.135	.050				
Active Gas.	.573	.672	.768	.865	.950	1.000	1.000	1.000	1.000
Neutral in Active Air.	2.372	2.768	3.163	3.559	3.954	4.120	4.120	4.120	4.120
Neutral in Active Gas.	.029	.034	.039	.044	.048	.051	.051	.051	.051
Total inactive or excess.	2.828	3.130	3.434	3.735	4.052	4.461	4.961	5.461	5.961
Per cent. inactive or excess.	.701	.696	.687	.680	.675	.686	.704	.729	.746

It should be noted how very slightly the increase in percentage of dilution increases with the excesses of air and gas; though the proportions may vary over 100 per cent., the dilution varies through but little more than 5 per cent. This is very striking, as will be noted again when the results of increasing dilution by neutral additions is taken up. There can be little doubt that the limits of combustibility is intimately associated with the per cent. of neutral or inactive gases present.

Next let us examine the calorific values of some of these mixtures, *i. e.*, the amount of heat that one cubic foot of gas can deliver when burnt explosively in mixtures within the limits of explosive combustion. The heat developed by a cubic foot of the gas in question is 691.59 B. T. U. when completely burnt, *i. e.*, in a chemical mixture, or in a mixture in which air is in excess, within of course the limits of combustibility.

Gas.	1	1	1	1	1	1	1	1	1
Air.	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
Gas Burnt, *i. e.*, Gas that could find Air Enough to Burn it.	.573	.672	.768	.865	.950	1.000	1.000	1.000	1.000
B. T. U. Available.	396.3	464.8	531.2	598.2	657.0	691.6	691.6	691.6	691.6

These results are shown graphically on the curve *A* of Fig. 9. Curve *B* shows the results of observations on the water gas used in the calorimeter and of unknown composition.

The calorimeter can was filled with 16.5 lbs. water for each run and the water equivalent determined by experiment to be 2.1 lbs. of water; this is for both can and coil. Radiation was assumed zero, as the temperature of the room was in every case between the initial water temperature and the final.

Four inches altitude of gas was used every time from the eighteen-inch tank mixed each time with varying quantities of air. The results are as follows reduced to cubic feet of gas:

B. T. U. PER CUBIC FOOT OF GAS WHEN MIXED WITH AIR.

Gas.	Air.	B. T. U. per cu. ft. Gas.
1	3.0	275.1
1	3.5	347.82
1	4.0	401.57
1	4.5	471.00
1	5.0	541.70
1	5.5	616.59
1	6.0	600.78
1	6.5	?

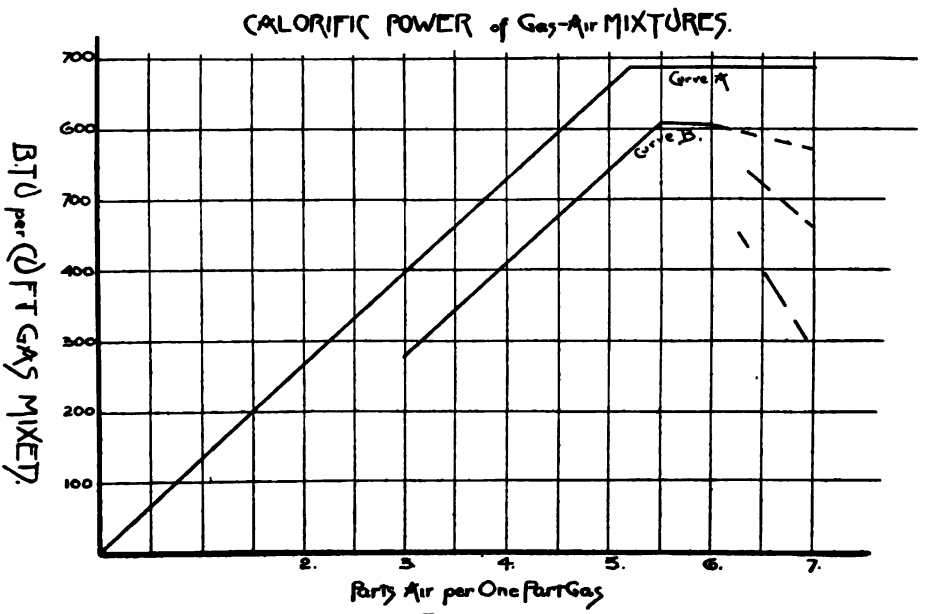


FIG. 9.

This is one set of readings, and the curve is a very good one. other sets of readings were taken, and if the results had been reduced to a mean the curve would have been perfect. The one set given were obtained in a space of about two hours. The values for mixtures 6.5/1 and 7/1 were very erratic but always below the maximum, and this result is extremely important, viz., *that very dilute mixtures after combustion has been started may cease to burn before combustion has become complete.*

It may be well to note a few peculiarities of this calorimeter before leaving the subject. When starting a continuous stream of sparks is provoked between the points and the mixture then turned on. As soon as the flame cap has settled and combustion is well started the spark may be turned off and attention turned to watching the thermometer and directing the stirring of the water. The feed may be depended upon to take care of itself. The process of starting, however, will not be successful unless good judgment in regard to certain points is exercised; however, a few trials are sufficient to show up these difficulties, and the means for avoiding them.

If the entering stream be so small in quantity as to give the gas too small a velocity through the feed pipe, then when the first part of the mixture reaches the spark there will be back-flashing, which may result in a succession of explosions. These successive explosions will have a period depending on the velocity of feed; they become more frequent as the velocity increases, until finally the velocity becomes high enough to force the flame beyond the feed pipe, when it will lodge in the rocks and stay there. It may even happen that the back-flash will extend to the trap, but no harm will be done except blowing off the rubber tube and causing a loss of the charge. At first this back-flashing was very troublesome and necessitated investigation. When the combustion chamber and coil were removed from the water no back-flash occurred even with a very slow feed, but a reinsertion caused the trouble to reappear. This was attributed to the intermittent back pressure effect of the bubbling of discharging gas through the water; it was then the flexible end to the coil was attached so that the discharge could be directed above during and below after starting, when it would do no harm. Since it was now shown that back pressure could have an appreciable effect on the action, and back-flash still occurring occasionally, the discharge gas coil of one-eighth inch copper tube shown in Fig. 1 was removed and the square coil of larger iron pipe substituted to reduce back pressure. The back pressure was thus made constant and less than originally, and the charge could be ignited at once without any failure with a constancy that was very gratifying.

Volume-ratios During Constant Pressure Combustion.

When the fire is enclosed and insulated the immediate effect of constant pressure combustion is to increase the volume of the gases(neglecting the small changes due to chemical regrouping of molecules). Knowing the amount of heat developed by the combustion and the specific heat of the gases, the volume increase should be easy to calculate. But in such a calculation no account can be taken of the large number of other influences, among them radiation, conduction, dissociation, etc., involving loss of heat to other phenomena that may be present and no assurance can be held out that the specific heat during the process is constant or equal to that of the products of combustion. A computation, therefore, by this the only method is of no value in engineering work, and the only way to obtain a result of real worth is to measure the increase directly under specified conditions. The method used has already been noted. The firebox consisted of a piece of six-inch standard steam pipe twelve inches long and the plates containing the orifices were of black iron one thirty-second of an inch in thickness. Unprotected, *i. e.*, with plates bare and pipe unlined, it was found for a pressure drop of four inches of Hg through each orifice that the maximum effect was $v_2/v_1 = 1.50$ for best mixture air and gas. Protecting the interior of the combustion chamber by one inch of fire clay and sand on the inside, the lower plate carrying a clay cone three inches high, and the upper plate protected externally by a quarter of an inch of asbestos sheets, the maximum effect was found to be $v_2/v_1 = 4.20$ for best mixture air and gas. Comparing the heating value of the gas used with that of say kerosene oil, and making an estimate of losses from above values it is *probable* that with the best mixture of kerosene and air that a value $v_2/v_1 = 6.00$ might be expected, but it must be remembered that this is only an estimate and of but little value compared with the last two figures of actual observations.

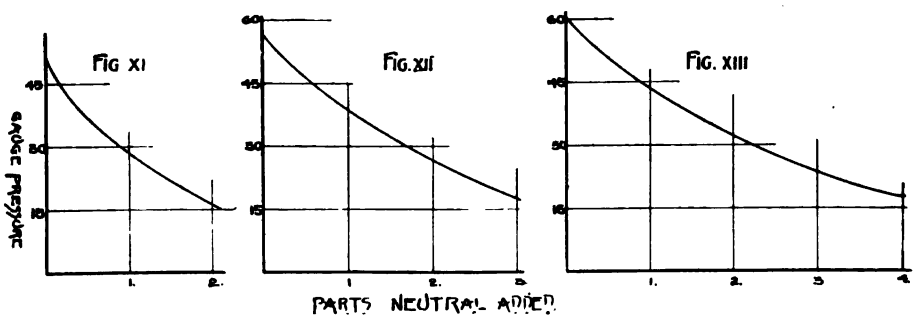
The apparatus used here was so certain in operation and constant in results that the readings could be obtained in a very short time and, when obtained, relied upon. The method of operation was as follows: The fire was started in the chamber with top plate removed; once burning steadily this plate was bolted down to

the flange and the whole allowed to heat up. The top orifice was originally the same size as the lower and as the fire pot heated up was continually reamed out to keep the manometer readings at the ratio of 2:1, *i. e.*, so that the drop in pressure was the same through both plates. When continued heating showed no increase in size of the top hole possible, then manipulation of the mixture was resorted to to cause, if possible, a rise in pressure in the combustion chamber and so permit a further enlargement of the upper opening to bring the pressure again to one half that existing in the lower chamber. Thus the maximum effect was obtained. It must be remembered that the readings included the friction effect of passing through the mass of broken rock forming the burner proper.

Pressure-Ratios for Constant Volume Combustion.

As is the case with volume ratios in constant pressure combustion it is impossible to calculate the values desired from calorific value and specific heat. Many determinations of the presence of ratios for various substances have been made but none for a wide range of mixtures including as one of the constituents neutral products of combustion.

Each mixture of air to gas within the range of combustibility was fired and then to each was added in turn successively increas-



FIGS. 11, 12, and 13.

ing amounts of neutral gases obtained by burning an explosive mixture as described.

It appeared that the resulting pressures were intimately connected with the percentage of dilution of neutral or excess gases,

and as the gas used has already exhibited some agreement with what is possible with the typical water gas chosen in comparison it will be well to work out a table of percentage of dilution of different mixtures and these figures will be placed on the curves of Figs. 11–16. The agreement and evident existence of a law is apparent.

WATER GAS OF NOTED COMPOSITION.

Mixture, $\left\{\begin{matrix}\text{Air, } 3\\ \text{Gas, } 1\end{matrix}\right\}$ diluted.

Gas.	Air.	Added Neutral.	Primary Neutral	Total Neutral.	Per cent. Neutral.
1	3	0	2.83	2.83	70.1
1	3	1	"	3.83	76.0
1	3	2	"	4.83	80.5
1	3	3	"	5.83	83.0

Mixture, $\left\{\begin{matrix}\text{Air, } 4\\ \text{Gas, } 1\end{matrix}\right\}$ diluted.

Gas.	Air.	Added Neutral.	Primary Neutral.	Total Neutral.	Per cent. Neutral.
1	4	0	3.43	3.43	68.7
1	4	1	"	4.43	74.0
1	4	2	"	5.43	77.6
1	4	3	"	6.43	80.6
1	4	4	"	7.43	82.8

Mixture, $\left\{\begin{matrix}\text{Air, } 5\\ \text{Gas, } 1\end{matrix}\right\}$ diluted.

Gas.	Air.	Added Neutral.	Primary Neutral.	Total Neutral.	Per cent. Neutral.
1	5	0	4.05	4.05	67.5
1	5	1	"	5.05	72.1
1	5	2	"	6.05	75.7
1	5	3	"	7.05	78.4
1	5	4	"	8.05	80.5

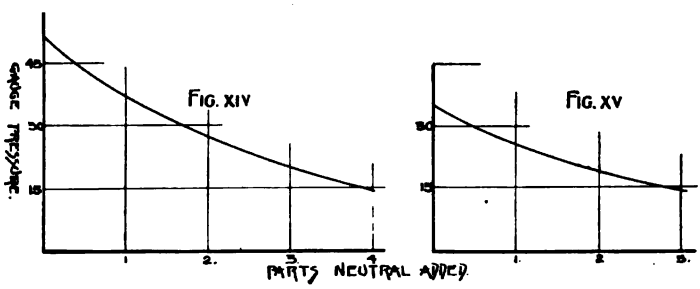
Mixture, $\left\{\begin{matrix}\text{Air, } 6\\ \text{Gas, } 1\end{matrix}\right\}$ diluted.

Air.	Gas.	Added Neutral.	Primary Neutral.	Total Neutral.	Per cent. Neutral.
1	6	0	4.96	4.96	70.4
1	6	1	"	5.96	74.4
1	6	2	"	6.96	77.3
1	6	3	"	7.96	79.6
1	6	4	"	8.96	81.3
1	6	5	"	9.96	84.0

Mixture, $\left\{\begin{matrix}\text{Air, } 7\\ \text{Gas, } 1\end{matrix}\right\}$ diluted.

Air	Gas.	Added Neutral.	Primary Neutral.	Total Neutral.	Per cent. Neutral.
1	7	0	5.96	5.96	74.6
1	7	1	"	6.96	77.3
1	7	2	"	7.96	79.6
1	7	3	"	8.96	81.3
1	7	4	"	9.96	83.0

The curves of Figs. 12–16 show the pressures given by the indicator for each mixture and are the mean values from a large number of lines drawn by the indicator. These curves are combined in Fig. 17, which is, therefore, a curve of pressures for all



FIGS. 14 and 15.

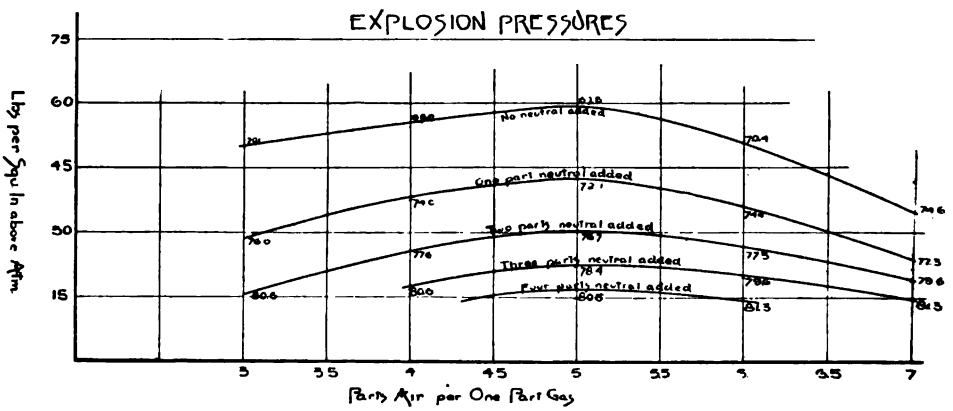

EXPLOSION PRESSURES
Lbs. per Sqr. In above Atm.
No neutral added
One part neutral added
Two parts neutral added
Three parts neutral added
Four parts neutral added
Parts Air per One Part Gas

FIG. 16.

mixtures diluted or not within the range of explosive combustibility. The numbers on the curves show the percentage of dilution of the typical water gas. The results are most remarkable

and can be accounted for only by assuming that the presence of a large amount of dilution hinders combustion. The limits at which combustion ceases to be possible on too great a dilution are here indicated, whether that dilution be due to excess gas, excess air or neutral gases. It will also be observed that the character of the diluent has an appreciable effect, but that when the dilution is least the pressure is greatest, about 60 pounds above atmosphere or a ratio of 5; and the presence of a constant per cent. of neutral will make combustion impossible no matter what the mixture of air and gas. The greatest neutral dilution gives the least pressure—about 15 pounds above atmosphere, or a ratio of about 2. These results give a reason for the decreased pressure in exploding gas-engines in which the mixture is always diluted by burnt products to an extent of 20–40 per cent. of the volume of neutral addition to the gas mixture which may already have neutral gas present to the extent of 65–70 per cent.

Neutral additions to the gases sent to the calorimeter and to the other apparatus showed, besides a corresponding and proper heat value for the resulting mixture, a decreased rate of propagation accompanied by a difficulty in ignition and constant tendency to incomplete combustion, *i. e.*, tendency to cease burning after inflammation had been started and before the mass had been entirely burnt.

THE CAMP BIRD GOLD MINE AND MILLS.

By H. A. TITCOMB.

In the southwestern part of Colorado lies the San Juan region, long known as a large producer of silver, and in recent years gold as well. The district shows evidence of former volcanic activity on a gigantic scale. Thermal springs still exist at Ouray, and the large areas of mineralized and oxidized rocks visible at many points have been attributed by some geologists to solfataric and hot-spring agencies.

The lowest exposed rocks are Algonkian quartzites and slates. Above these are limestones (Lower Carb, or Devonian?); then conglomerates, sandstones and quartzite (Jura-Trias), and quartzite

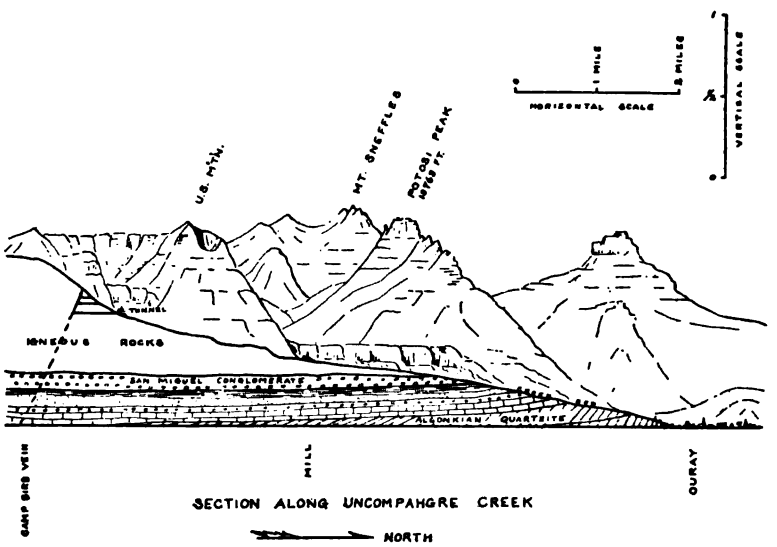


FIG. 1.

and shale (Cretaceous). The highest of the sedimentaries is the thick-bedded red conglomerate known as the San Miguel formation (Eocene). Overlying these aqueous strata is a vast thickness of igneous rocks which occur in almost horizontal layers. These lines of stratification are supposed to mark the periods of the successive flows and eruptions which buried the sedimentary rocks thousands of feet deep beneath the breccias, tuffs, and other volcanic debris. (See Figs. 1 and 2.)

The entire mass of aqueous and plutonic rocks has been subjected to stresses which have resulted in numerous zones of fracture, sometimes traceable from the cap of rhyolite down through the breccias and the lowest sediments These zones of fracture seem to favor certain strikes: thus the N E.–S. W. and the N. W.–

FIG. 2. Contact of San Miguel Conglomerate (Tertiary) with the overlying Andesitic Breccia.

S. E. and other series have been described in the reports of the U. S. Geol. Survey and elsewhere. Many of the fractures have been filled with vein matter, commonly quartz and evidently deposited from solution. The veins seem to weather away more

easily than the surrounding country rock and the melting snows wash away the disintegrated vein matter, leaving miniature cañons with smooth, regular walls, and sometimes broad couloirs near the lofty summits, packed with snow and ice. This peculiarity often enables one to see the veins for miles extending over mountain and valley. Many of the veins carry precious metals in quantity to be commercially valuable.

In the vicinity of the Camp Bird Mine, the andesite breccia and the Intermediate Series are generally regarded as the most productive horizons. Higher up, where the veins enter the rhyolite, they often seem to be narrow and comparatively barren of their valuable contents. With the Camp Bird as the most notable exception, the San Juan has been almost entirely a silver producer. In the case of the Camp Bird, however, almost the entire value of the ore is in the gold. Since the country rock is the same in both classes of veins—andesitic breccia—a different subterranean origin of the ore-bearing solutions would seem to offer a plausible explanation of the varying occurrence.

After the volcanic activity had ceased, erosion began its work and an enormous amount of material was removed by the action of waters, leaving cañons and cliffs and lofty peaks which render the scenery of the "Silvery San Juan" among the finest in Colorado. Avalanches are of yearly occurrence and are a factor in the general degradation. At the Liberty Bell mine last winter, near the mining town of Telluride, a series of avalanches swept over the buildings and the grove of pines above the mine, burying all beneath the mass of snow and ice and resulting in the loss of over twenty lives. So great is the power of these snow-slides that large trees are sometimes broken or overturned by the blast of air caused by by the rushing snow.

The Camp Bird Mine lies in Imogene Basin at an elevation of about 11,300 feet * above sea level. From the town of Ouray (7,712 feet elevation), a good wagon road leads southward up the steep valley of the Uncompahgre for five miles to the Camp Bird Mills. Thence the road continues two and one half miles farther up to the mine. The mill and mine are connected by a Bleichert tramway (see Fig. 3) some 10 00 feet in length, which transports the ore down to the mill and carries light supplies up to the mine. The

* Aneroid measurements, averaged, between Ouray and the mine.

wooden piers or towers which support the tram are protected by ocation and by buttresses against snow-slides.

The mine itself presents an example of ordinary overhand stoping of a high-grade quartz vein. The vein or veins sometimes attain a width of ten to sixteen feet, but would average less than

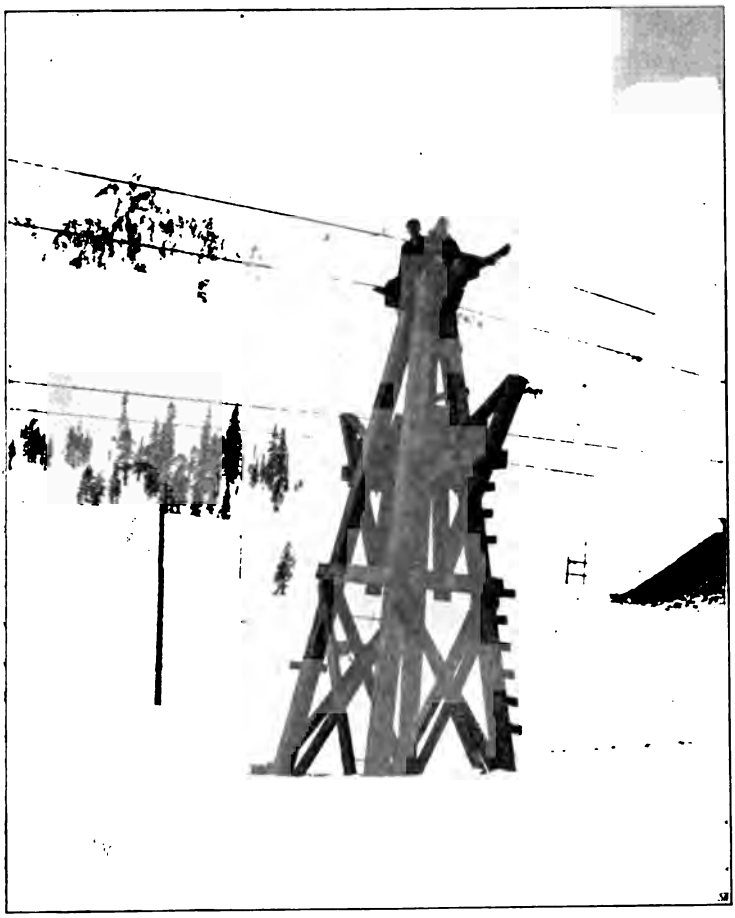


FIG. 3. Bleichert Tramway. Cliffs in the background are Potosi Rhyolite, the topmost series of the igneous rocks.

this: probably three to eight feet. The veins have a southerly dip of about 70° from the horizontal, varying considerably in places, the variations giving rise to gentle rolls or undulations. Pay ore is not continuous throughout the extent of the vein, but

the values are concentrated in certain areas of the deposit, these areas constituting ore "shoots." Often a cross vein occurs near or at these pay areas, and these cross veins may sometimes be responsible for the localization of values in the main vein. When followed away from the main vein for a considerable distance, the cross vein as a rule becomes barren, the "Big Discovery" being a possible exception. No law governing the occurrence of the ore shoots has as yet been announced by the engineers who have examined this mine.

The gangue is largely quartz, and there are almost universally present pyrite, galenite and sphalerite, which occur either in bands of heavy sulphides or scattered and disseminated through the ore. The country next to the vein is usually altered, sometimes to the extent of obliterating its brecciated texture. It frequently carries pyrite in small grains or crystals, but this pyrite seldom holds values. Sometimes rhodonite occurs in considerable amount, rendering that portion of the vein exceedingly hard and tough. Softer portions of the vein show black oxides of manganese, clay, talc and other oxidation products. As a rule, no gold is visible except on close examination of very rich streaks of ore. The ore might be classed as free-milling.

Three cross-cut tunnels, each with its corresponding level, have been driven through the breccia, opening up the veins for a vertical distance of about 500 feet. The lowest or "New Tunnel" is 2,300 feet in length, passing this distance through the country rock before striking the vein. This tunnel is 7 x 7 feet in section and its arrangement is shown in Fig. 4. The grade of the tunnel is four inches per 100 feet, and the levels and tunnels are all single track, a twenty-inch gauge being employed. Mules (two per shift) haul out eight cars of ore in a train, each car holding about one ton. Mule haulage has proved very satisfactory, and easily handles the 210 gross tons milled per twenty-four hours. The ore from the upper workings is dumped into chutes leading down to the third or lowest level, and thence hauled out to the Bleichert tramway. Two shifts of eight hours each constitute a day, the miners shooting at 4 A. M and 4 P. M. This allows a large part of the gases produced by the shots to escape before the men return to work at 7 o'clock. Even after this interval of three hours, some of the innermost workings retain much gas, which causes headaches and decreases the energy and activity of the men working in these

places. By allowing the valves of the air pipes in the mine to remain partly open during the absence of the men, compressed air is permitted to escape and the atmosphere very much improved.

Where a level has run through pay values a stope is commenced, about six to eight feet in height being cut out above the level, which is then stulled and lagged. Openings are left at intervals of forty to fifty feet along the level for the chutes and manways

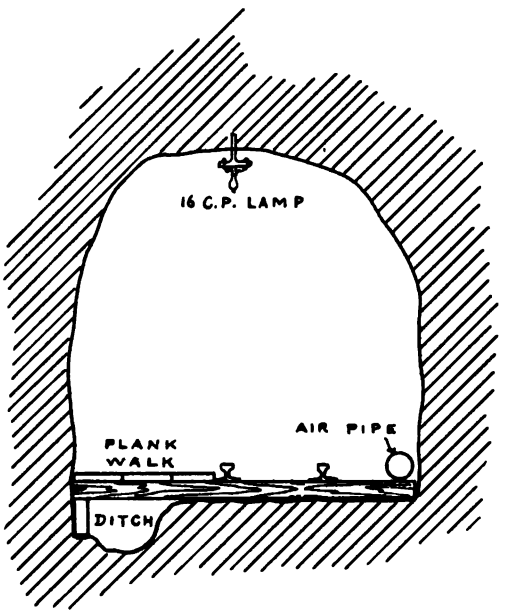


FIG 4.

which will give access to the coming stope. A second cut of six to eight feet of ore is next shot down on top of the lagging which now forms the roof of the drift, using light charges of explosive so as to avoid injury to the timbering, and subsequent cuts add successively to this broken ore, the excess being shovelled down the ore chutes to the cars in the level below.

As the stope is thus carried upwards in the pay ore, the timbermen keep pace with the machine men and timber and lag the

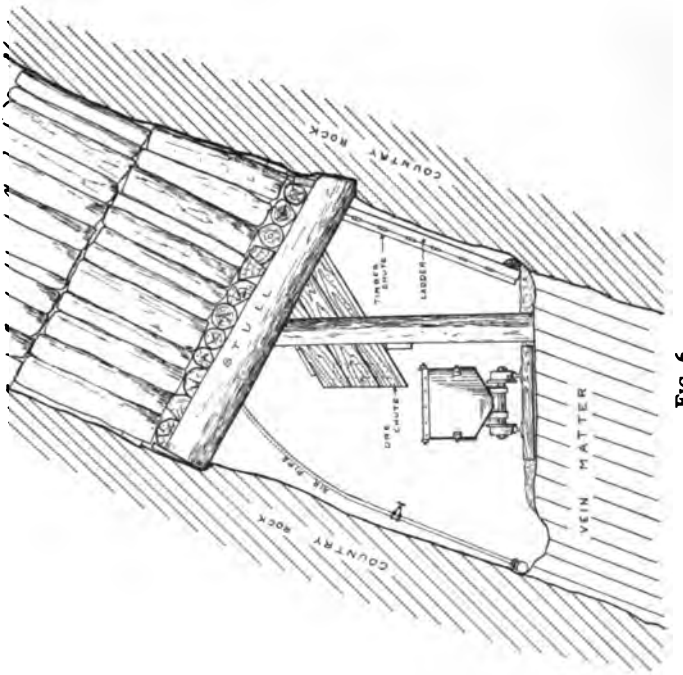

COUNTRY ROCK
STULL
TIMBER CHUTE
LADDER
ORE CHUTE
VEIN MATTER
COUNTRY ROCK

FIG. 6.

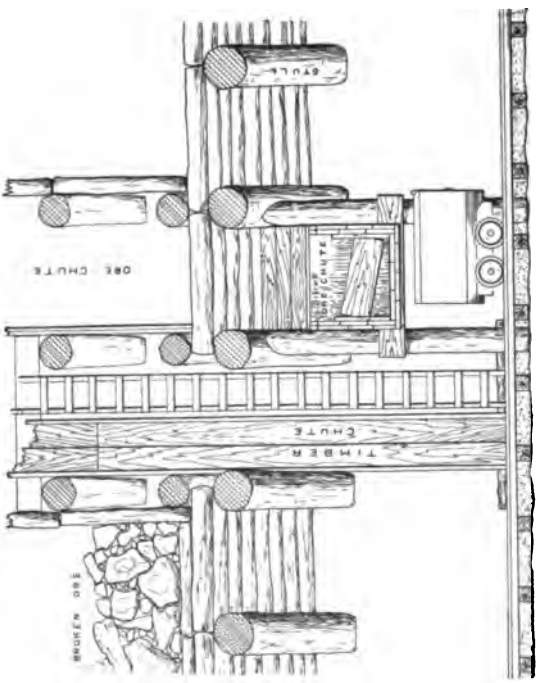

STULL
ORE CHUTE
TIMBER CHUTE
BROKEN ORE

FIG. 5

chutes and manways so that they are kept open to the top of the pile of broken ore, which acts as a footing on which the miners can work at the unbroken ground overhead. The writer has calculated that in stoping in the Camp Bird, from 50 per cent. to 60 per cent. of the ore by weight remains in the stopes, and from 50 per cent. to 40 per cent. is removed and milled.

When the back of a stope becomes low grade, if it be deemed advisable to abandon further stoping, the lagging of the chutes is removed beginning at the top, and the ore is run down and hauled out to the tramway. The ore finally remaining directly over the drift must be shovelled into the chutes in order entirely to clear the stope. In thus drawing a stope it is usual to put in numerous stulls as the level of the broken ore is lowered, these stulls being left to support the walls of the now open stope. Where waste rock is available it can be advantageously run into an open stope.

The timbering of chutes and manways is indicated in Figs. 5 and 6, which represent, respectively, longitudinal and cross sections taken on 2d Level of the Camp Bird Mine near chute No. 28.

Sullivan, Ingersoll–Sergeant, and Rand air drills are used in mining, and all give satisfaction. In the wider stopes and in hard rock as well as in drift work, a 3¼-inch machine is employed, requiring two men for its operation. It raises and in softer ground or narrow stopes, a drill with 2 inch or 2¼-inch piston is used, one man alone operating such sizes. These small sized drills are known to the miners as "Babies" and "Chippies."

Air at 100 pounds pressure per square inch is brought in through the tunnel and levels by 6-inch and 4-inch pipe and taken up manways by 1- to 2-inch pipe to the stopes above. Metal wound rubber hose joins the air pipe to the machine, 50-foot lengths of hose being found advantageous as giving considerable mobility to the machines. At the mine are two 100-horse-power Rand compressors and one 200-horse-power Riedler compressor. These are driven by electricity, with steam as an auxiliary in case of accident to the electric system. The electric power is supplied by the Telluride Power Co. at 10,000 volts, which is transformed to 400 volts before use at the motors. The cost of the current is $7.00 per horse-power-month. It is possible that the presence of the auxiliary steam attachments is of advantage in tending to

prevent any marked rise in the cost of electric power. The speed of drifting is 80 to 120 feet per month; of raising, 60 to 80 feet per month.

Wages of Miners and Trammers		$3.00 per 8 hours.
"	Machine men (large drills)	4.50 " " "
"	Chuck men " "	4.00 " " "
"	Machine men (small drills)	4.00 " " "
"	Mule drivers	3.25 " " "
"	Timbermen	3.50 " " "
"	Blacksmiths	4.00 " " "
"	Blacksmith's helpers	3.25 " " "

In raises and winzes, small-machine men receive $4.50 per shift.

MILL.

The mill is arranged as follows:

6 Grizzlies, 1 x 2 inch bars, spaced 2 inches c. to c., 40° slope.

3 Crushers, Blake pattern, 9 x 15 inch jaw opening.

Ore bins, about 900 tons capacity.

Automatic feeders.

60 Stamps, 850 lbs. each, 6 inch drop, 100 drops per minute, 4 inch discharge.

25 mesh No. 27 wire battery screens.

Outside copper plates, 4½ x 16 ft. (No inside amalgamation used.)

Hydraulic classifiers.

30 Frue Vanners and 5 Wilfley tables, treating classified material (coarse, medium, fine, and slimes). Corrugated belts are used on the vanners treating the coarsest material.

The mill stamps 190 to 220 gross tons of ore per 24 hours, the average being about 3.5 tons per stamp. Chrome steel shoes and dies are found most satisfactory, having a life of 90 to 100 days of 24 hours.

The amalgamating plates are dressed every 3 hours, and are cleaned up twice in 24 hours. No sodium amalgam is used in the "quick" (mercury), a double retorting being found sufficient to keep the quick in good condition.

The concentrates are shoveled into an iron car and trammed to the dry-house, where they are partially dried by an arrangement of steam pipes. They are then sacked in heavy canvas sacks holding about 110 lbs. each. If the concentrates were completely dried, there would result much loss, due to fine particles sifting

through the canvas of the sacks. It is found better to leave a slight percentage of moisture which acts as a bond. The concentrates are shipped to the smelter at Pueblo, Colorado. Power for the mill, machine shop, carpenter shop, etc., is furnished, during a large part of the year, by a 7-ft. Pelton water wheel, operating under 170 lbs. pressure. When the water is low, a 250 H. P. Tandem Compound Allis Corliss engine is employed, or a combination of this engine and the Pelton wheel. It would be more

FIG. 7. 275 Ton Vats in Cyanide Mill. Note tailings distributors by which the vats are filled. The distributors consist of hollow revolving arms which work on the principle of the Barker's Mill.

satisfactory to employ different water wheels for the crushers, the stamps, the vanners, etc. By using separate and independent motors, a shut down of the stamps, for any reason, would not interfere with the crushing or shop work.

CYANIDE PLANT.

The tailings from the mill pass by gravity to the lowest floor of the cyanide plant, and are thence elevated by centrifugal sand

pumps to the vats above. These sand pumps are a source of considerable trouble, and the expensive linings of manganese steel are soon worn out by the sharp tailings. It would have been better practice to establish the cyanide plant at a lower elevation (or the stamp mill at a higher elevation) and thus employ gravity for the transfer of the tailings.

At the cyanide plant the tails undergo either a "single" or a "double" treatment. The single treatment takes place in large wooden vats, holding 275 to 300 tons each, and the leachings and washings occupy 13 days on the average. In the double treatment, the stamp mill tails are first leached in upper vats, holding 85 tons each, and then the contents of these vats are shoveled through trap doors into the lower vats (also of 85 tons capacity) where a further leaching is performed. The double treatment requires about 9 days' time; but, except a decrease in time, it seems to present no advantage over the single treatment, and the cost of shoveling out an 85-ton tank is $9.00 (3 men at $3.00). The supposed advantage of the double treatment was to break up any lumps or layers impervious to the solutions, and to permit the access of the oxygen of the air to all parts of the tailings.

After the cyanide treatment is completed, the barren tailings are sluiced out of the vats and allowed to run to waste. The auriferous cyanide solutions are passed through zinc boxes, where the gold is precipitated in the form of impure black slimes. These slimes are treated with sulphuric acid which dissolves most of the zinc. They are then dried over furnaces in large iron trays, and afterwards treated in a small reverberatory furnace. This latter treatment calcines the carbonates of lime and magnesium. The calcined slimes are next fluxed * in large, graphite crucibles, and the slag skimmed off and sacked. This slag carries 8 oz. gold per ton, and is shipped to the smelter. The impure bullion is finally refined and shipped to the U. S. Mint at Denver.

REFERENCES TO LITERATURE ON THE SAN JUAN REGION AND THE CAMP BIRD MINE.

F. V. Hayden. U. S. Geol. Surv., 1873–4.

G. E. Kedzie. Transactions Am. Inst. Mining Eng., 1888, Vol. XVI., p. 570.

* The flux used consists of: Powdered borax, 5 parts; soda bicarbonate, 2½ parts; sand, 1 part. Use 1 part of flux to 2 parts of gold slimes.

Whitman Cross. Proceedings Colo. Sci. Society, Sept. 7, 1896.

Chester Wells Purington. "Telluride Quadrangle," U. S. Geol. Surv., 18th Report, Part III., 1896–97.

J. F. Kemp. "Ore Deposits of the United States," pp. 287–90, ed. 1900.

F. L. Ransome. "Silverton Quadrangle," Bulletin No. 182, U. S. Geol. Surv., 1901.

R. H. Downer. "Ouray County Mines," Bulletin Colorado School of Mines, Dec., 1901.

C. W. Purington, Thos. H. Woods and G. D. Doveton. "The Camp Bird Mine and Mills," Trans. Am. Inst. M. E., May, 1902.

NEW GRAPHICAL METHODS IN CRYSTALLOGRAPHY.*

By AUSTIN F. ROGERS.

(With Plate I.)

Value of Graphical Methods.

To anyone who has worked in determinative crystallography the value of graphical methods is apparent. A graphical method for the solution of a crystallographic problem serves a twofold purpose:

1. It furnishes a check on calculation. The work must be checked in some way and graphical methods if sufficiently accurate are preferable to duplicate calculations.

2. It presents a picture of the mathematical operation involved and often enables one to see which of two courses to follow, more readily than do the formulæ used in calculation.

Previous Use of Graphical Methods.

Goldschmidt has treated the graphical solution of crystallographical problems quite elaborately in his "Ueber Projektion und graphische Krystallberechung." He solves the gnomonic projection completely for angles, elements and indices, but as developed by him it is so intimately connected with his polar symbols and elements that only those familiar with his system use it to any ex-

* From Ph.D. Thesis.

tent. In spite of some advantages of other notations for crystal faces and forms the Miller indices are decidedly the most compact and convenient.

Experience has shown that, all things considered, the most elegant method of representing the relative positions of the faces of a crystal, the zones which they form, and the kind of symmetry with which they are arranged, is by means of the stereographic projection.

The stereographic protractors recently designed and described by Penfield * may be applied to the graphical solution of certain crystallographic problems, but these do not include the chief problems of crystallography, namely, the determination of the indices and the axial elements from the measured angles or conversely the determination of the angles from assumed indices and elements.

In the complete determination of a crystal there are three stages of calculation:

1. Calculation of indices from measured angles.

2. Calculation of axial elements from indices and measured angles.

3. Calculation of theoretical angles from axial elements and assumed indices.

It is the purpose in this paper to point out the fact that a graphic method suffices for the first stage, the determination of the indices and that it furnishes a check on subsequent calculation of theoretical angles from the indices and axial elements. Hence we have two stages of the calculation instead of three and the proper importance is given to the graphical determination.

Calculation may not be dispensed with, but except in work for record and comparison the graphic method, as outlined in the following pages, serves for the complete determination of the morphology of a crystal without any calculation whatever.

Graphical Determination of Indices.

A graphical method, perhaps the one best adapted to general use for the determination of the indices and elements, has been elaborated in another article in this issue of the Quarterly.† In general the construction is limited to one quadrant and so does not interfere with the rest of the projection.

* *Amer. Jour. Sci.* (4), 11; 1–24, 115–143. 1901.

† pp. 11–22.

PLATE I.

Protractor for Determining Indices. Designed by Austin F. Rogers.

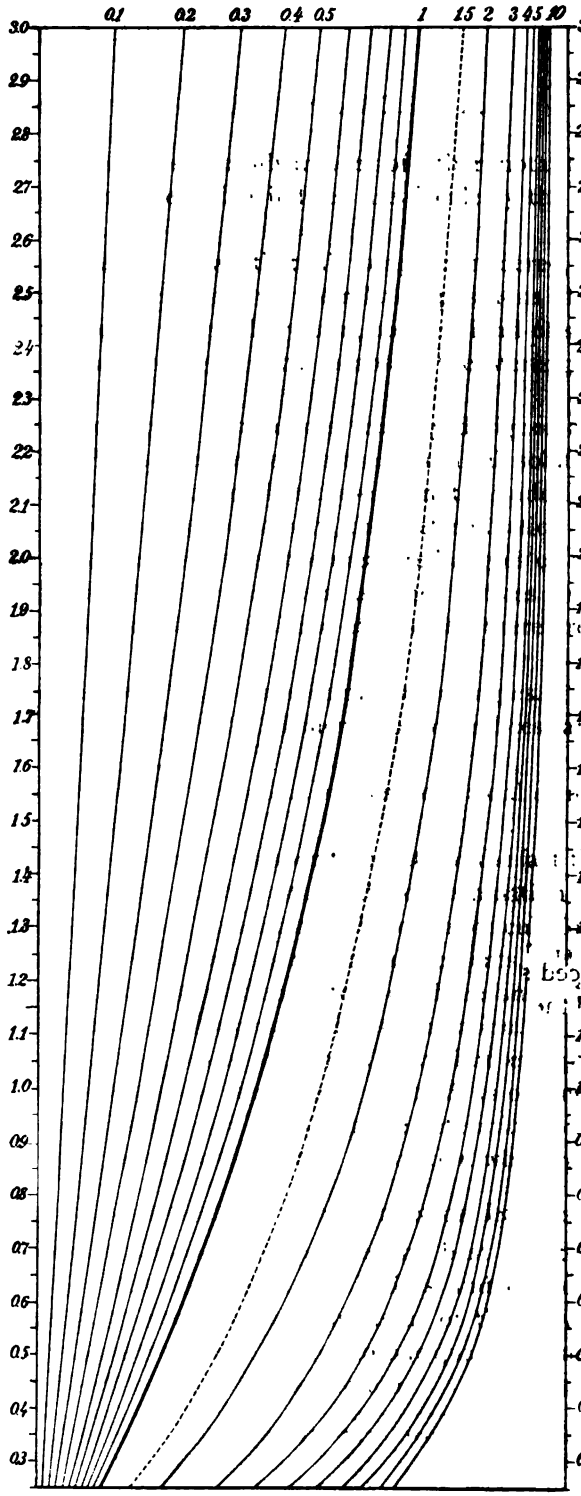


PLATE I.

Protractor for Determining Indices. Designed by Austin F. Rogers.

But the disadvantage of this method is that it involves extra construction. It is important for the beginner to follow the construction, but after this is understood the protractor about to be described may be employed.

A New Protractor for the Direct Determination of the Indices from the Stereographic Projection.

Plate I. may be cut out and used as a protractor for the determination of indices of faces in the radial zones of the orthometric and hexagonal systems directly from the stereographic projection. The protractor is of a size to be used with a circle of 7 cm. radius, such as the divided circle printed on the sheets designed by Penfield,* and was constructed as follows: Two parallel lines were drawn 7 cm. apart and were divided on a decimal of 7 cm. = unity. On the horizontal line, connecting the parallels at 1, stereographic degrees, the tangents of which are equal to numbers 1 to 10 and tenths from 0.1 to 1.0 were laid off. On several other horizontals similar points were determined.

On the line at 2, for instance, the distance on 1 marked 1 is laid off as ½. On the line at 3 the distance marked 3 on 1 is laid off as 1, and so on. The corresponding points on all horizontal lines were connected, thus forming a system of curves. The unit line is heavier than the others.

To determine the indices of the faces of a radial zone the protractor is pla· · so that the vertical lines are perpendicular to the zone line anc en moved along until the unit line of the protractor falls upon the pole of the unit face, the radial zone always being parallel to the horizontal lines of the protractor. The indices of other faces are read off directly. If the zone is [001 : *okl*: 010] the ratio k/l is indicated. For instance if line 2 of protractor falls upon a pole of a face the indices of that face are 021. If the zone is [001 : *hol*: 100] the ratio h/l is given. In the zone of unit pyramids [001 : *hhl*: 110] h/l is given. The ratio h/k in any *hkl* (or *hko*) is not obtained directly from the protractor, but may be found by locating the corresponding *okl* and *hol* by zone circles (protractor No. IV. of Penfield) and then determining their indices as above.

If the protractor is placed so that its unit line falls upon the pole of the face (*hkl*) in which $k/l = 1$, the ratio k/l of the other faces

* loc. cit.

of the zone are given. If placed so that the unit line falls upon a pole of a face (*hkl*) in which $h/l = 1$, the ratio h/l of other faces results. Or the graphic method given in the article referred to on a preceding page may be employed for the determination of the ratio h/k and the protractor used for the determinations of the ratios k/l and h/l.

In the monoclinic system only the ratio k/l may be determined by the protractor. The protractor is placed on the imaginary orthorhombic zone from center of projection to position 010.

Graphical Determination of Axial Ratio.

In the radial zone [001 : 010] or [0001 : 11$\bar{2}$0] or the imaginary orthorhombic zone of the monoclinic, the value of the axis $\dot{c}$ is indicated by the reading on the vertical lines, or if the radial zone is [001 : 100] the value a/c is similarly given.

Graphical Determination of Angles.

The protractor may also be used to determine the angle which a dome form with known indices makes with other faces of the zone if the axial ratio is known. For instance to find angle (001 : 021) if $\dot{c} = 1.35$. Determine the distance in stereographic degrees (measured on protractor I.) of 2 line from the left vertical along the horizontal line connecting the 1.35 points. To determine angle [001 : 102] if $a/c = 2.1$, find along the line connecting the 2.1 points on the protractor the distance in stereographic degrees of the ½ line (k/l) from the left vertical line.

In spite of the limitations of the protractor it may prove useful and a fair degree of accuracy is claimed for it. For the determination of faces with complex or very high indices it cannot of course take the place of more accurate graphic determination, but such faces occur rarely.

It may be used in the orthometric and hexagonal systems for the complete determination of a crystal, including indices and axial ratios, from the stereographic projection without calculation or construction.

Example.

Let Fig. 11 (p. 15 in preceding article) represent one quadrant of the projection of an orthorhombic crystal. To determine from the projection the axial ratio and the indices of all faces. Assume certain faces *o*(011), *m*(110) as unit faces. Draw zone circles

through *C*, *B* and *A*. The *okl* planes corresponding to pyramids *f*, *z* and τ are located by protractor IV. upon radius *CB* at (—), o and δ respectively. The *hol* planes corresponding to *f* and χ are located at *l*, *z* at (—), τ at (—), upon radius *ac*.

Take the zone [001 : 010]. Place unit line of protractor on o, then a is located at 0.12 (a little over 0.1); (—), at 0.25 ν, at 0.33; φ, at 0.5; ϑ, at 2.0; β, at 3.0. $\dot{c}$ as indicated on verticals of protractor is 1.29, the calculated value being 1.289.

Zone circles through *o* and *m* show that 101, which does not occur on the crystal lies at (—). Then using protractor on zone [001 : 100] we find *l* at 0.25, *e* at 0.33, *d* at 0.50, (—) at 2.0. a/c as indicated on vertical is 1.6. $\breve{a}$ may be found by prolonging radius through 110. Then distance $AT = \breve{a} = 0.782$, calculated being 0.785.

Hence the indices of the faces are as follows.

The coördinate angles of some of the forms as found by the protractor together with the calculated values are also given to show the accuracy of the determination of the coördinate angles when the indices and axial elements are known.

		ρ Found.	ρ Calc.
a	018	9° 15′	9° 9′
ι	014	18 5	17 52
ν	013	23 0	23 15
ϕ	012	32 40	32 48
δ	021	69 0	68 48
β	031	75 20	75 30
l	104		
e	103		
d	102		
f	114		
z	111		
τ	221		
χ	144		
t	121		
s	132		

Graphical Determination of Indices from Interfacial Angles.

In spite of the great advantages of measurements by means of the two-circle goniometer and of the convenience of coördinate angles for the purpose of record and comparison it may be found at times more convenient to make use of the one-circle goniometer and interfacial angles.

There is a convenient method for graphically determining the indices from the interfacial angles. In the orthometric and hexagonal systems, and certain zones of the monoclinic and triclinic the method is exactly the same as that given under the coördinate angles, simple relations existing in these cases between the coördinate and interfacial angles. In other zones of the monoclinic and triclinic a slightly different method is employed.

We may illustrate the principle by one zone of a triclinic crystal, for instance the zone $\bar{B}CB$ (Fig. 21, p. 21).

Let Fig. 20, p. 21, be horizontal projection of zone in question. From B (010) lay off angles BH (010:okl) BD (010:011) BC (010:001) BD' (010:011) BH' (010:okl), etc. (These angles are found from the projection by protractor No. II. of Penfield.) Draw radii through these points. Then the intercepts which the radii make on a line drawn parallel to BB' are in the ratio of the indices. If the line is located so that the distance RT between the radii through C (001) and D (011) is equal to unity of the scale line,* then $RT' = k/l$. Similary if D is $0\bar{1}1$, RT is 1, and $RT' = \bar{k}/l$. For a zone BKB' the distances RT and RT' are in ratio of k/k', if P is $h1l$ then $RT' = k'$. Similarly for zone APD if P is 1 kl, $RT' = l'$. For the zone CPL, if P is $hk1$, $RT' = l'$..

THE MAGNETIC PROPERTIES OF IRON AND STEEL AT LIQUID AIR TEMPERATURES.†

By C. C. TROWBRIDGE.

Liquid air has been the means of extending research in the various branches of physics to extremely low temperatures. Among the investigations of industrial importance that have been made are those relating to the effect of low temperatures on the magnetic properties of iron and steel. It is the purpose of this paper to give a brief account of these investigations and the results obtained. A statement first in regard to the temperature of liquid air will not be out of place, and an account of the results of measurements of the peculiar magnetic property of liquid oxygen should be of interest.

* Radius of circle is a convenient unit. (Scale No. 4 of Penfield sheets.)

† Published in the *Electrical World and Engineer*, August 30, 1902.

The Temperature of Liquid Air.

If a quantity of atmospheric air is liquefied its temperature becomes approximately —191.5° C. at normal pressure. Liquid air, however, changes in composition when it is boiling, the percentage of nitrogen in it diminishing while that of oxygen increases. This change occurs because the boiling point of liquid nitrogen at atmospheric pressure is —194.5° C. and that of liquid oxygen —182.5° C., and the former liquid boils away at a higher rate than the latter. It follows that boiling liquid air also changes in temperature. If liquid air is allowed to boil for a considerable time its temperature gradually approaches that of liquid oxygen, —182.5° C., but when it is used for experimental purposes its temperature is usually about —185° C. The temperature of the liquid air is, therefore, at least 200° C. below normal room temperature, which is generally considered 20° C. This difference gives a wide range of temperature for experimental purposes. In addition, opportunity is offered of studying the properties of materials at the very low temperature of —185° C. While considerably lower temperatures than this have been obtained by Professor James Dewar and others, research in this direction has been confined mainly within the low temperature limit mentioned.

Extremely low temperatures have been obtained by liquifying hydrogen, which has a boiling point of — 252.5° C., or 20.5 absolute. At — 258 C, hydrogen becomes a solid, and has been cooled to — 260° C., the lowest temperature obtained. These temperatures have been measured by hydrogen and helium thermometers. Below — 200° C. resistance thermometers are unreliable, owing to the fact that below that temperature curves of resistance do not follow any general law, and because at very low temperatures the slightest impurity in the metal brings about a considerable difference of resistance from that of the pure metal.

The investigations on the effect of low temperatures on the magnetic properties of iron and steel which have been made, have been on the strength of permanent magnets and on magnetic permeability and hysteresis in iron and steel, liquid air being employed to cool the specimens tested to about —185° C. The results of the investigations will be presented separately. Experiments of this nature are of industrial importance, for they will unquestionably lead to a more definite knowledge of the molecular

changes in iron and steel when subjected to magnetic influences. It is to such experiments that the great progress in practical electricity is primarily due. The subjects to be presented will be taken up in the following order:

(1) The magnetic permeability of liquid oxygen and liquid air. (2) Experiments at low temperatures on permanent magnets. (3) Magnetic permeability and hysteresis in iron and steel at low temperatures. (4) General summary of the results of the experiments described.

Magnetic Permeability of Liquid Oxygen and Liquid Air.

The magnetic permeability of liquid oxygen as compared to that of other liquids is very high, as can be seen from the results of an investigation of Fleming and Dewar, who have studied the magnetic permeability of liquid oxygen and liquid air. They found that the magnetic permeability of liquid oxygen is 1.00287. This number is the ratio of the magnetic permeability of liquid oxygen to that of cold gaseous oxygen, and by the same method used in the given determination no difference was detected between the magnetic permeability of gaseous oxygen at −182 C. and at normal temperatures. The value 1.0024 was obtained for liquid air, its magnetic permeability being chiefly due to the liquid oxygen it contained.

Later, the same investigators determined the magnetic permeability of liquid oxygen, employing a different method from the one previously used, and obtained the value 1.0041, which is not very different from their first measurement (about one part in a thousand). They, however, consider the latest value, 1.0041, more accurate than the former, 1.00287.

In the course of these experiments relating to the magnetic permeability of liquid oxygen, Professors Fleming and Dewar measured the magnetic susceptibility of crystallized manganous sulphate in the form of a powder. They found that the susceptibility of the salt at 25° C. is to that at −182° C. in the ratio of 105 to 349, or 1 to 3.32. The centigrade temperatures, 25° C. and −182° C., correspond to 298 and 91 degrees on the absolute scale. Thus it is evident that the magnetic susceptibility of the solid manganous sulphate "is increased by cooling, so that its value varies inversely as the absolute temperature, and is increased threefold by cooling to the temperature of liquid air."

They also measured the diamagnetic susceptibility of bismuth at both 15° C. and −182° C. and found that it increased only 16 per cent. at −182° C.; and therefore, that it is not increased inversely as the absolute temperature on cooling.

A short table is given herewith to show a comparison of the magnetic permeabilities of various liquids. The values for permeability (μ) were calculated by the use of the formula $\mu = 1 + 4\pi k$ from determinations of magnetic susceptibility (k) of liquids, made by various investigators. The value for susceptibility for liquid oxygen according to the latest figures is over five times as great as that for ferric chloride, one of the most magnetic of the iron salts, the magnetic permeability of which is given fourth in the following table:

TABLE I.

MAGNETIC PERMEABILITY OF VARIOUS LIQUIDS.

Liquid.	Permeability (μ).	Determined by
Liquid oxygen	1.0041 (Latest)	F. & D.
Liquid oxygen	1.00287	F. & D.
Liquid air	1.00240	F. & D.
Ferric chloride (sat. sol.)	1.00072	Townsend.
Manganese chloride	1.00019	Wähner.
Cobalt chloride	1.000038	"
Nickel chloride	1.000023	"
Water (D .9993)	.999993	"
Water	.999990	*

All of these values are, however, far below that of the so-called non-magnetic iron alloys. Twelve per cent. manganese steel, usually called non-magnetic, has a magnetic permeability of 1.3 to 1.4.

An important note relating to the investigation on the magnetic permeability of the liquid oxygen, by Fleming and Dewar, has been published by the authors, and is as follows: "In connection with the above investigation, it is interesting to note one remarkable difference between the magnetic susceptibility of oxygen in the liquid and in the gaseous state. The mass of 1 c.c. of gaseous oxygen, taken at 15° C. and 760 mm. is 0.00134 gram. The mass of 1 c.c. of liquid oxygen, taken at −182° C. and 760 mm. as determined by one of us (J. Dewar), is 1.1375 gramme. Hence, the ratio of the density of liquid oxygen to that of gaseous oxygen is 849 to 1.

* Mean of results of six investigations.

"The magnetic susceptibility of gaseous oxygen at 15° C. and 760 mm., as obtained from the figures given by Faraday and E. Becquerel, is 0.143×10^{-6} per unit of volume, whilst the magnetic susceptibility in the liquid state is, as we have shown, 228×10^{-6}. Hence the ratio of the magnetic susceptibility of liquid oxygen to that of gaseous oxygen for equal volumes is 1594 to 1.

"In other words, the magnetic susceptibility of liquid oxygen is nearly twice as great as that of gaseous oxygen of equal masses. The inference is that magnetic susceptibility is not merely a property of the molecule *per se*, but is a function of the state of aggregation."

Experiments on the Strength of Permanent Magnets.

Dewar has investigated the effect of lowering the temperature of permanent magnets to −182° C. and determining their magnetic moments at +15° and −182° C. through several cycles of temperature change between these limits. Subsequently, more extensive experiments of the same nature were performed by Dewar and Fleming together. Among the conclusions reached by them are the following:

"1. That the sudden cooling of the temperature of liquid air usually permanently decreases the magnetic moment of short magnets made of many varieties of steel, assuming them to have been magnetized initially in a strong field.

"2. This initial decrease is found both in hardened steels having great coercive force and also in the same steels in a soft or annealed condition, and especially conspicuous in the case of the 19 per cent. nickel steel.

"3. In the case of most steels so far examined the effect of cooling magnets made of them to −185° C. is to temporarily increase the magnetic moment after the permanent magnetic condition has been reached.

"4. The exceptions of the above rule so far noted are the nickel steels with percentages of nickel from 19 to 29 per cent., in which case the magnetic moment is always decreased temporarily by cooling to −185° C. after the permanent condition has been reached."

In the experiments just referred to, performed by Dewar and Fleming, the steels tested were magnetised at normal temperatures and then subjected to temperature changes through the range +15° to −185° C.

The writer has recently made a series of experiments with permanent magnets which were magnetized at the temperature of liquid air (−185° C.). The magnetic strength of the magnets were shown by their magnetic moments determined by means of a magnetometer. The magnetic moments obtained by magnetization at approximately −185° C. were compared with the magnetic moments of bars of the same steel obtained by magnetization at normal temperature, 20° C. The change of magnetic strength produced by heating bar magnets to 20° C. which had been magnetized at −185° C. was determined also and compared with the change produced by cooling magnets of the same steel to −185° C. which had been magnetized at 20° C. The experiments were chiefly confined to carbon magnet steel and tungsten magnet steel. Among the results obtained were those given below, which are shown for convenience in tabular form.

In these experiments the initial change of magnetic strength or the first gain or loss in the magnetic moment, accompanying the first change of temperature of the bars of steel after they were magnetized was determined, because it has been shown that the change of magnetic strength of a permanent magnet due to a change of temperature depends partly on the previous history of the magnet. Special care was taken not to jar the magnets throughout the experiments, and also to determine their magnetic moments immediately after magnetization.

Three bars of carbon steel, size 83 x 10 x 3 millimeters, weighing 24.45 grams, were heated together to a red heat and then hardened in water at 20° C. They were magnetized at −185° C. and then immediately warmed to 20° C. The magnetic moments at these temperatures were as follows:

TABLE II. (*a*).

CARBON STEEL MAGNETIZED AT −185° C.

Magnet.	Magnetic Moment at −185° C.	Magnetic Moment at 20° C.	Difference (Loss).	Percentage (Loss).
1	211	131	80	37.9
2	202	140	62	30.6
3	211	147	64	30.3
Mean				32 9

Another bar of this steel of the same dimensions and weight as the magnets 1, 2 and 3 and hardened with them, was magnetized at 20° C. and then immediately cooled to —185° C. The magnetic moments at 20° C. and —185° C. were as follows:

TABLE II. (*b*).

CARBON STEEL MAGNETIZED AT 20° C.

Magnet.	Magnetic Moment at 20° C.	Magnetic Moment at —185° C.	Difference (Loss).	Percentage (Loss).
4	208	189	19	9.1

It is evident that the initial loss in magnetic moment due to change of temperature when the steel is magnetized at —185° C. and then warmed to 20° C. is much greater than for the reverse operation, although in either case a considerable loss in the magnetic moment is the result of a change in temperature of the steel of 205 degrees.

These carbon steel magnets, 1, 2, 3 and 4, were allowed to rest undisturbed for nine days at approximately constant temperature (room temperature in April). Their magnetic moments were then determined, and are given in Table III.

TABLE III.

CARBON STEEL: TOTAL LOSS OF MAGNETIC MOMENT AT THE END OF NINE DAYS.

Magnet.	Original Magnetic Moment.	Magnetic Moment After 9 Days.	Difference (Loss).	Percentage (Loss).
1	211	127	84	39.8
2	202	136	66	32.6
3	211	138	73	34.6
4	208	170	38	18.2

Magnets 1, 2 and 3 were magnetized at —185° C. and then warmed to 20° C. The total loss of magnetic strength of these magnets since magnetization was approximately twice as much as magnet 4, which was magnetized at 20° C., cooled to —185° C. (with a loss of 9.1 per cent.), and then warmed to 20° C. again.

Tungsten Steel from Sheffield.—Three bars of tungsten steel, sizes 89 x 2 x 3 millimeters, each weighing 5.05 grammes, were hardened together in water at 20° C. They were magnetized at —185° C., and then warmed to 20° C. The magnetic moments at the two temperatures were as follows:

TABLE IV. (*a*).

TUNGSTEN STEEL MAGNETIZED AT 185° C.

Magnet.	Magnetic Moment at —185° C.	Magnetic Moment at 20° C.	Difference (Loss).	Percentage (Loss).
1	212	179	33	15.5
2	228	192	36	15.7
3	232	206	26	11.2
Mean				14.1

A bar of this steel, hardened with magnets 1, 2 and 3, was magnetized at 20° C. and then cooled to —185° C. The magnetic moments obtained were as follows:

TABLE IV.

TUNGSTEN STEEL MAGNETIZED AT 20° C.

Magnet.	Magnetic Moment at 20° C.	Magnetic Moment at —185° C.	Difference (Loss).	Percentage (Loss).
4	213	200	13	6.1

Bundle of iron wires (not pure iron), 9 cm. long, heated to a red heat and cooled in air at 20° C., magnetized at —185° C., and then warmed to 20° C., showed the following loss of magnetic strength :

TABLE V.

IRON WIRE MAGNETIZED AT — 185° C.

Magnetic Moment. at — 185° C	Magnetic Moment. at 20° C.	Difference (Loss).	Percentage. (Loss).
22.3	13.5	8.8	39.4

Another fact is shown by these experiments; approximately the same magnetic moment is produced, whether the steel is magnetized at 20° C. or —185° C., other conditions being equal. This is evident from a comparison of the magnetic moments obtained after magnetizing steel bars at —185° C., with the magnetic moment obtained after magnetizing a bar of the same steel at 20° C.

TABLE VI.

CARBON STEEL, MAGNETIZED AT —185° C. AND AT 20° C.

Magnet.	Magnetized at	Magnetic Moment.
1	—185° C.	211
2	—185° C.	202
3	—185° C.	211
4	+ 20° C.	208

TABLE VII.

TUNGSTEN STEEL, MAGNETIZED AT —185° C. AND AT 20° C.

Magnet.	Magnetized at	Magnetic Moment.
1	—185° C.	212
2	—185° C.	228
3	—185° C.	232
4	+ 20° C.	213
5*	+ 20° C.	232

The writer's experiments on the magnetization of steel at liquid air temperatures seem to warrant the following general conclusions.

1. That approximately the same magnetic moment is obtained whether a bar of tungsten steel or carbon steel is magnetized at normal or at liquid temperature, other conditions being equal. This is evident from a comparison of the magnetic moments obtained after magnetizing steel bars at —185° C., with the magnetic moment obtained after magnetizing a bar of the same steel at 20° C.

2. That the initial loss in the magnetic moment, due to change of temperature, of a bar of steel magnetized at —185° C. and then heated to 20° C. is much greater than when the bar is magnetized at 20° C. and then cooled to —185° C., a considerable loss occurring in both cases.

3. That there is a certain amount of unstable magnetism in a newly made steel magnet, which tends to permanently disappear at the first change of temperature in either direction from that at which magnetization takes places, much more of the unstable magnetism passing off by heating than by cooling.

Concerning these results, Mr. F. A. Giffin makes the following suggestions, that "in the light of the molecular strain hypothesis, the fact that molecular rigidity increases with descending temperatures may explain the relative rapid recovery, *i. e.*, decrease in magnetic moment of those bars which were magnetized at lower temperatures. In other words, the strained condition of a magnetized cold bar is relatively artificial, and any rise in temperature tends to leave its molecules free to respond to the restoring action of internal stresses. It would appear that the molecular moment due to the magnetic field was large in comparison with the opposing intermolecular moment developed in the bars under experiment; this would make the magnetic moment independent of the

*5 magnetized previously at — 185° C.

temperature." This assumption is, of course, meant to refer to the initial magnetic moment, or that immediately after magnetization, and it seems most probable that it would be found to be true for strong magnetizing forces, while perhaps not for those that are very weak.

It is necessary here to call attention to the fact that in several cases mistakes have been made by writers in stating the results of investigations on magnetism at low temperature. Among these is the following statement, taken from Thompson's "Elementary Lesson in Electricity and Magnetism," edition of 1901, p. 104:

"Trowbridge found severe cooling at 100 degrees below zero to destroy the magnetism of steel magnets; but Dewar has observed that when cooled to $-185°$ C. in liquid oxygen the magnetic properties of the iron are nearly twice as high as at 0° C."

What Professor John Trowbridge found was as follows: That a bar magnet magnetized at 6° or 8° C. when cooled from 4° C. to $-25°$ C. lost less than 4 per cent. of magnetism. For a greater reduction of temperature, to about $-80°$ C., a far greater percentage loss of magnetism was observed. In one case a bar magnet magnetized to saturation lost 66 per cent. of its magnetism.

The latter part of the statement quoted above probably refers to an investigation of Fleming and Dewar, on the permeability of iron and steel at liquid air temperatures, the results of which are given below.

Permeability and Hysteresis Loss of Iron and Steel at Low Temperatures.

Fleming and Dewar found in an extensive series of measurements that the magnetic permeability of annealed soft Swedish iron decreased when cooled to low temperature, but that the permeability of unannealed Swedish iron increased as the temperature diminished. In the case of hardened iron, the permeability increased several hundred per cent. when the iron was cooled to liquid air temperature. These results were for both weak and strong magnetizing forces.

A steel pianoforte wire behaved the same as annealed soft iron; when a strong magnetizing force was used its permeability decreasing over 50 per cent. when cooled from 0° to $-200°$ C.

These investigators found that for various induction densities the hysteresis loss was the same at $-186°$ C. as at normal tem-

perature. Curves showing effect of low temperatures on magnetic permeability of iron and steel, according to Fleming and Dewar, are given on the following page.

T. Claude has also studied the magnetic properties of iron at low temperatures. According to his experiments, for high induction densities, the permeability and hysteresis loss of iron are the same at —186° C. as at 20° C., except for a slight tendency toward diminution at the low temperature. For low induction densities the permeability and hysteresis loss diminish with the temperature to a marked extent.

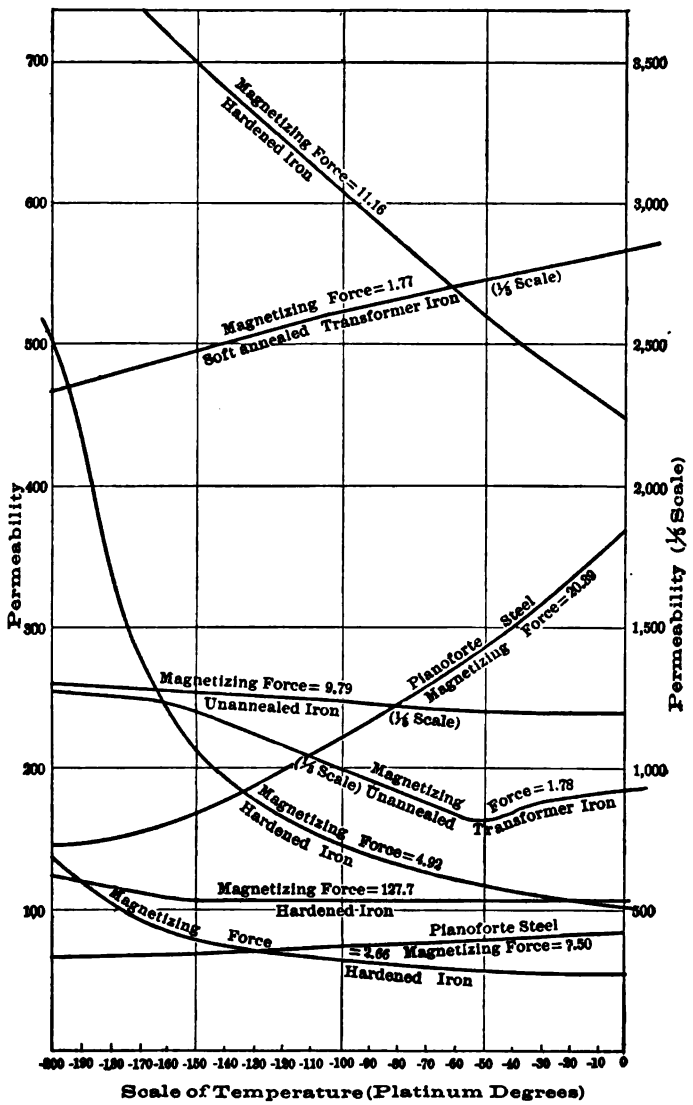
A. H. Thiessen has investigated the hysteresis of iron and steel at 100° C., 20° C. and that obtained by using solid CO_2 (about —80° C.). He found that for soft wrought iron, the hysteresis losses increase with decreasing temperature when the maximum magnetizing force causes approximate magnetic saturation, and that the reverse is true for low magnetizing forces.

The same effects of temperature are found for annealed crescent tool steel.

In the case of 5 per cent. nickel steel, for a maximum magnetizing force, the hysteresis loss likewise increased as the temperature diminished. While these results are in agreement with previous determinations at very high temperatures, they are not in agreement with the results of Fleming and Dewar and Claude, who found that the hysteresis loss of soft iron was the same at 20° C. and about —185° C. Thiessen, however, did not experiment below —80° C. Fleming and Dewar refer to the experiments of Lows and Warren, who found that the hysteresis loss in very soft steel began to decrease only after the material was heated to above 150° C.; after that it decreased regularly in accordance with the simple linear function of the temperature.

In one experiment where Lows and Warren tried with the same material cooled to —78° C. in solid carbonic acid and ether, they found no difference between the hysteresis loss of soft steel at that temperature and at normal temperatures.

The results of these experiments clearly indicate that determinations of the magnetic properties of iron and steel at different temperatures largely depend on the composition and the degree of hardness of the samples tested. It is most probable that the difference in the results of the experiments cited above is due to a difference in the material used in the tests and the conditions of


Permeability
Permeability (⅓ Scale)
700
600
500
400
300
200
100
8,500
3,000
2,500
2,000
1,500
1,000
500
Magnetizing Force=11.16
Hardened Iron
Magnetizing Force=1.77
Soft annealed Transformer Iron
(⅓ Scale)
Pianoforte Steel
Magnetizing Force=20.59
Magnetizing Force=9.79
Unannealed Iron
(⅓ Scale)
(⅓ Scale) Unannealed
Magnetizing Force=1.78
Transformer Iron
Magnetizing Force=4.92
Hardened Iron
Magnetizing Force=127.7
Hardened Iron
Magnetizing Force
Pianoforte Steel
=2.66 Magnetizing Force=7.50
Hardened Iron
-200 -190 -180 -170 -160 -150 -140 -130 -120 -110 -100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0
Scale of Temperature (Platinum Degrees)

the experiments, rather than any mistakes on the part of the investigators.

It will be difficult to formulate laws in regard to the magnetic properties of iron and steel at very low temperatures, unless the complete analysis of the material and the thermal and the mechanical treatment of the samples immediately previous to the experiments are known.

General Summary of the Results of the Experiments Described.

The credit of the greater part of the work done thus far on magnetism at low temperatures is due to Professors James Dewar and J. A. Fleming, who have made a number of investigations together in England. Work has also been done by Professor T. Claude, in France, and the writer in this country.

A brief general summary of the results of the experiments described is given below. The investigations made, while not entirely conclusive in some cases, seem to indicate the following facts:

1. It appears that liquid oxygen has a magnetic permeability that is considerably higher than other liquids, but far below the magnetic permeability of the so-called non-magnetic iron alloys, and that, at least in the case of liquids, magnetic susceptibility is a function of the state of aggregation rather than merely a property of the molecule *per se*.

2. That the magnetic moment of a permanent steel magnet is independent of the temperature at which magnetization takes place, and that a change of temperature in either direction after magnetization will cause a permanent loss in the magnetic strength of the magnet, the amount of this loss depending upon the composition and the hardness of the steel and the number of degrees change in temperature to which the bar is subjected.

It is also evident that steel magnetized at liquid air temperature in a strong field becomes saturated magnetically almost instantly, as it does at normal temperatures. That when a magnet has been subjected to a series of temperature changes, has lost some of its initial magnetic strength and has reached a permanent condition, that cooling (to liquid air temperature) causes an increase in the magnetic moment, and that heating diminishes the magnetic moment. That steels containing 19 to 29 per cent. of nickel behave in an exceptional manner, for the effect of cooling them

to — 185 degrees is to temporarily decrease the magnetic moment after the permanent magnetic condition has been reached.

3. That the magnetic permeability of annealed soft iron is less at liquid air temperatures than it is at normal temperatures, but if the iron is hardened then the magnetic permeability becomes greater at the low temperature. Highly tempered steels, however, appear to behave like annealed soft iron, the low temperature having the effect of diminishing the magnetic permeability.

4. Two separate investigations have thus far been made on the effect of liquid air temperatures on the hysteresis loss in iron for high induction densities. The results obtained are in agreement and indicate that under these conditions the hysteresis loss is the same at normal and very low temperatures.

For low induction densities, one investigation showed the hysteresis loss the same at both temperatures, while in another it was found that the hysteresis loss diminished in a marked manner when the iron was reduced to the temperature of liquid air.

ABSTRACTS.

ANALYTICAL CHEMISTRY.

By ELWYN WALLER.

Calculating Water Analyses. Fisher (*Analyst*, XXVII., 137). When one has obtained the amounts of bases as Na_2O, CaO, etc., and of acids (Cl, SO_3 CO_2, etc.) dividing each amount by the molecular weight of that particular constituent will give the molecular proportions of each. If the analysis is correct, the sum of these molecular proportions for the bases should be the same as that for the acids. Then, since the combinations are in molecular proportion, multiplyingt he molecular proportion of any constituent by the molecular weight of the salt of which it is assumed to form a part gives directly the amount of that salt. The sample cited is as follows:

	Found.		Mol. wts.		Mol. proportions.
Na_2O	53.14	÷	62	=	0.8571
MgO	11.99	÷	40	=	0.2990
CaO	35.28	÷	56	=	0.6300
				Sum =	1.7861
Cl_2	18.00	÷	71	=	0.2535
SO_3	103.88	÷	80	=	1.2985
CO_2	9.55	÷	44	=	0.2170
N_2O_5	0.84	÷	108	=	0.0077
				Sum =	1.7767

The molecular weights of Na_2O, Cl_2 and N_2O_5 are taken, because they are the equivalents of CaO, SO_3, etc.

In this case, assuming that all Cl and all N_2O_5 are present respectively as NaCl and $NaNO_3$ (residual Na_2O as Na_2SO_4), also that all MgO is present as $MgSO_4$ (residual SO_3 as $CaSO_4$ and residual CaO as $CaCO_3$) the results would be worked out thus:

2 NaCl	$0.2535 \times 117 = 29.66$
2 $NaNO_3$	$0.0077 \times 170 = 1.31$
Na_2SO_4	$0.5959 \times 142 = 84\ 62$
$MgSO_4$	$0.2990 \times 120 = 35.87$
$CaSO_4$	$0.4036 \times 136 = 54.89$
$CaSO_3$	$0.2264 \times 100 = 22.64$
Total Salts	229.00

which should agree essentially with results by evaporation.

The factor 0.5959 for Na_2SO_4 is obtained by deducting the sum of those for Cl_2 and for N_2O_5 (0.2535 + 0.0077) from the molecular proportion of Na_2O found (0.8571); similarly by deducting the sum of residual SO_3 and of MgO (0.5959 +0.2990) from that for total SO_3 (1.2985) we obtain the factor 0.4036 for $CaSO_4$. In the same manner for the $CaCO_3$.

It is evident that the application of this mode of reasoning may be used to calculate approximately the amount of alkalies present, if the other constituents have been determined.

Hydrochloric Acid free from Arsenic. Thome and Jeffers (*Proc. Lond. Chem. Soc.*, XVIII., 118). Dilute until sp. gr. is about 1.10, then heat to boiling and introduce a piece of fine copper wire gauze. The Cu should be as pure as possible. For 2 liters of acid about 4 inches square of 100-mesh gauze should be used, rolled loosely about a glass rod flattened at the end that it may readily be removed. Keep the acid just boiling for an hour. Then remove the gauze and put in a fresh piece, continuing until the gauze remains bright; then distill the acid, using a fresh piece of gauze. It may be deemed advisable, though it is an extra precaution, to reject the first 20 cc. of distillate.

Obtaining Zinc free from Arsenic. Hehner (*J. S. C. I.*, XXI., 675). Melt a pound or two of ordinary spelter in a clay crucible. Throw in metallic Na in the ratio of about 1 gm. Na to 1 lb. Zn. Stir with a piece of hard glass tubing (iron rods for stirring are likely to be arsenical). Remove the black scum which appears by use of a china spoon or crucible lid held in the tongs. Stir vigorously and remove the scum from time to time until the Na appears to have oxidized out; then add another piece of Na and stir again. Finish by pouring into a fresh crucible and repeating the Na treatment. Cool somewhat before granulating in order that thinner flakes of the metal may be obtained. If the molten metal is poured into very dilute acid the product is more satisfactory as to purity. A zinc which is quite arsenical may be thus purified, but it is best to start in with one which is fairly pure.

Destroying Organic Matter to Apply Tests for Metals, etc. Meillere (*J. Pharm. Chim.*, XV., 97). The most rapid and satisfactory method consists in the use of $KHSO_4$ in combination with a mixture of H_2SO_4 and HNO_3.

To attack 250 gms. of organic matter, mix the strong acids in the proportion of 100 cc. H_2SO_4 to 400 cc HNO_3. Add 5 gms. $KHSO_4$ to the organic substance and 100 cc. of the acid mixture, heat until liquefied, and run the acid mixture in lowly (200 cc. in one hour) maintaining the heat. From time to time evaporate 1 cc. of the liquid in a capsule. If it blackens the oxidation is incomplete.

Rubrescin, a New Indicator. Rosenfed and Silber (*Chem. Ztg. Rep.*, XXVI., 130). A mixture of 50 gms. resorcinol and 25 gms. chloral hydrate in a flask are brought to a temperature of 106° C. in an oil bath. Once started the reaction proceeds without further heating, evolving HCl. The product is a brittle non-hygroscopic mass. Pulverize and purify by washing with $CHCl_3$ in which the rubrescin is insoluble. It is sparingly soluble in ether, soluble in warm amyl alcohol or in cold methyl or ethyl alcohol. Red with alkalies colorless with acids, or if used in larger porportion, pale yellow. Very sensitive.

Alkaline Hydrate or Bicarbonate in Presence of Monocarbonate. North and Lee (*J. S. C. I.*, XXI., 322). Titration with normal acid and phenolphthaleine indicator gives an end reaction accurately, provided the

tip of the burette is immersed in the liquid. The presence of such amounts of chloride as usually occur in commerical soda ash is without influence. (Excessive amounts of chloride *will* affect the result.) At this point all the available Na_2O has been converted to $NaHCO_3$. Adding methyl orange and titrating gives results on which the proportions of Na_2CO_3 and $NaHCO_3$ may be calculated.

The method was checked up by use of Lunge's method, also by separate determination of CO_2.

For H_2O in soda ash ignite 10 gms. to constant weight. From the loss in weight deduct H_2O necessary to afford that equivalent to $NaHCO_3$ as found by the titration, and reckon the remainder as moisture.

Free Lime in Cements. Maynard (*Bull. Soc. Chim.*, Paris, XXVII., 858). Glycerin may be used to extract the CaO while it has no effect on other constituents of the cement. Weigh out 0.5 gm. of the cement in an Erlenmeyer flask. Measure out 50 cc. pure (anhydrous) glycerin at 60° C. Pour upon the sample, allow the vessel in which the glycerin was measured, to stand, and measure the amount adhering, to obtain (by difference) the exact amount of glycerin used. Plug the neck of the Erlenmeyer with cotton, agitate for some minutes, and keep at 40° C. or over for 5 days. Then filter off the major part of the glycerin, keeping the temperature for filtering and measuring, at 60° C., at which temperature it is very fluid.

After measuring, the amount of CaO extracted may be determined by alkalimetric titration.

Alumina in Alums. White (*J. Am. Chem. Soc.*, XXIV., 457). If a solution of an alum, to which has been added Rochelle salt ($NaKC_4H_4O_6$) is titrated with $Ba(OH)_2$ (N/5) the $Ba(OH)_2$ used will correspond to the SO_3 combined with Al_2O_3 plus free acid (SO_3 combined with K_2O, or Na_2O is not estimated). If a duplicate solution of the alum is evaporated to dryness, redissolved in neutral citrate ($Na_3C_6H_5O_7$) and titrated with $Ba(OH)_2$, a smaller amount is required, and the difference between the two amounts of $Ba(OH)_2$ used is equivalent to one-third of the Al_2O_3.

Titanium in Irons, etc. Waterhouse (*Ch. News*, LXXXV., 198). Treat 5 gms. of drillings with 50 cc. HCl, evaporate to dryness and bake, redissolve in HCl and filter. Wash as closely as possible and preserve the insoluble residue. Bring the solution to about 150 cc., nearly neutralize with NH_4OH, clearing by use of a few drops of HCl, should it become turbid, add about 50 cc. Na_2SO_3 (1 : 5) when the iron is reduced — add 50 cc. glacial acetic and 20 gms. $NaC_2H_3O_2$ — boil 15 minutes, let settle and filter. Unite the precipitate with the insoluble residue from evaporation, burn off filter paper, graphite, etc., and fuse the whole with 10 gms. Na_2CO_3, maintaining the fusion for several minutes. Extract with about 150 cc. hot water, wash well, rinse off precipitate into a beaker, dissolving what may adhere by use of HCl, add 10 cc. diluted H_2SO_4, evaporate to strong fumes, cool, dilute and filter off SiO_2, etc., dilute the filtrate to 150 cc., reduce what Fe may be present by use of 20 cc. Na_2SO_3 solution, add glacial acetic and $NaC_2H_3O_2$ as before, boil hard 15 minutes, and filter off TiO_2 for ignition and weighing.

Manganese in Irons. Noyes and Clay (*J. Am. Chem. Soc.*, XXIV. 243). Dissolve 1.5 gms. in 25 cc. HNO_3 or 20 cc. HNO_3 with 5 cc. HCl. Transfer to a 300 cc. flask, nearly neutralize with Na_2CO_3 then add ZnO until $Fe_2(OH)_6$ begins to form. Wait two minutes, then add excess of ZnO. Make up to the mark, mix well and filter off 200 cc. Add $NaC_2H_3O_2$ solution and then Br. water, boil to precipitate the MnO_2. Filter and wash well. Dissolve the precipitate on the paper by dropping on it from burette an acid standard solution of $(NH_4)Fe(SO_4)_2$ (8.56 gms. of the crystallized salt with 40 cc. of 23 per cent. H_2SO_4 in one liter) running the solution into the beaker in which precipitation was effected. Titrate back with standard solution of $K_2Mn_2O_8$.

Zinc Titration with Na_2S. Prothiere (*J. Pharm. Chim.*, XV., 419). For the "spot test" the author recommends the use of paper saturated with tartar emetic solution.

The end reaction is when a yellow stain is produced with a drop of the solution. The paper may be preserved indefinitely and gives a sharp end-reaction.

Separation of Nickel and Zinc. Rosenheim and Huldschinsky (*Ber.* XXXIV., 3911). To the solution of the two metals, in at most 50 cc. add 12 gms NH_4CNS, and agitate with a mixture of 1 vol. amyl alcohol to 25 vols. ether. Zn only is dissolved by the etherial solution, Ni remaining in the aqueous solution. *Avoid* the presence of HNO_3.

Separation of Nickel and Cobalt. Modification of Rose's Method. Taylor (*Chem. News*, LXXXV., 269). The mixed sulphides are to be dissolved in HCl with a crystal of $KClO_3$ and the solution evaporated to obtain it as nearly neutral at possible. Then add precipitated $BaCO_3$ (or $CaCO_3$) and Br water. Allow to stand with frequent shaking for five minutes, cobalt if present separates as black hydrated Co_2O_3 — the Ni remaining in solution. The presence of free CO_2 solution exercises a pronounced retarding effect.

Qualitative for Cobalt. Danziger (*J. Am. Chem. Soc.*, XXIV., 578). To about 5 cc. of the solution acid with HCl in a test-tube add solid ammonium thioacetate, $CH_3CO{\cdot}NH_4$, a few drops $SnCl_2$ solution, and an equal volume of amyl alcohol. Shake well and allow to stand so that the mixture separates in two layers. If Co is present, the upper layer will be colored blue. For the amyl alcohol may be substituted a mixture of acetone and ether, or of alcohol and ether. If the solution has little or no color of its own to mask the tints, this will detect 1:500000.

The compound formed was found to be $(CH_3COS)_2Co.2CH_3COS{\cdot}NH_4$.

Arsenic in Coke. Archbutt and Jackson (*J. S. C. I.*, XX., 448). After drying, treat 50 gms. with 100 cc. strong HNO_3 (gr. 1.42), heating for at least two hours. Dilute to about 500 cc.—then filter and wash—evaporate to dryness on a water bath—then add 25 cc. conc. H_2SO_4 and heat to strong fumes—dilute with water and evaporate again to fumes. Repeat at least three times to expel all N oxides. Transfer to a flask, add 23 gms. NaCl, and 2 gms. $FeSO_4$. At this point the entire bulk of the solution should not be over 100 cc. Distil until the temperature of boiling reaches 125° C., by which time all the As will be in

the distillate. To that add a little ZnS, and agitate. Filter off the As_2S_3, wash with H_2S water. Boil with 300 cc. of water for two hours. Filter, concentrate to about 40 cc., cool, add 0.5 gm. $NaHCO_3$ and some starch and titrate with N/100 I solution.

Antimony in Ores. Petriccioli and Reuter (*Ztsangew. Chem.*, XIV., 1179). Treat 0.5 to 5ms. according to richness with 50 cc. HCl and 50 cc. water. Heat at 70° C for nearly an hour, filter, wash first with acidified water afterward with water alone, add $H_2C_4H_4O_6$, dilute to 750 cc. warm to 60 to 70° and precipitate with H_2S. Wash, and then rinse the Sb_2S_3 back into the beaker, add 50 cc. HCl and heat until all odor of H_2S is gone. Dilute until a slight turbidity is shown, which is removed by a few drops of acid. Titrate at once with standard $K_2Mn_2O_8$ ($K_2Mn_2O_8$ corresponds to 5 Sb.) Products containing the higher oxides of Sb may require to be brought into solution by alkaline fusion, and the operation conducted on Sb_2S_3 precipitated a second time to obtain it free from admixture with S.

Separation of Arsenic Antimony and Tin. Lang, Carson and Mackintosh (*J. S. C. I.*, XXI., 748). Experimental. The metals were precipitated together as sulphides. After washing these were evaporated to dryness with conc. HNO_3, and the residue extracted with water and filtered. In the solution As was determined by Mg mixture.

The residue was digested for an hour with conc. solution of $H_2C_4H_4O_6$ which extracted all Sb, leaving SnO_2 which was ignited and weighed. Sb was separated as sulphide, converted to Sb_2O_4 and weighed in that form. The test analyses show fairly good results.

In experimenting with another method of separation, As_2S_3 was found to be perceptibly soluble in HCl.

Arsenic and Antimony in Ores. Skinner and Hawley (*Eng. and Min. Jour.*, 1902, 148). The important feature of the process is the point that when a mixture of H_2S group sulphides is distilled with HCl solution of $CuCl_2$, As distils over as $AsCl_3$. Sb will also distil over if the operation is conducted with the passage of HCl gas through the retort. Prepare a solution of 300 gms. $CuCl_2$ in one liter of HCl (gr. 1.2). Also dissolve 1 lb. Zn. in 500 cc. water and 1250 cc. HCl (gr. 1.2), and evaporate until the solution boils at 180° C. Mix equal volumes of these solutions.

Treat 1 gm. of the ore with 10 cc. conc. HNO_3, heat until red fumes cease, add 10 cc. H_2SO_4 conc. and evaporate to copious fumes. Cool, add H_2O and HCl (also $H_2C_4H_4O_6$ if Sb is present) filter, precipitate by H_2S, and wash free from Fe. Rinse into the distilling flask by use of HCl, add 50 cc. of the CuZn solution, and distil until the temperature at which the mixture boils is 115° C. Add 10 to 25 HCl and distil again. (The second distillation will be unnecessary if the proportion of As is small.) Determine As by adding excess of $NaHCO_3$ and titrating with standard I solution.

For Sb, after distilling off all As, pass a currect of HCl gas and distil to dryness repeating until the distillate gives no precipitate with H_2S after adding $H_2C_4H_4O_6$. Filter the Sb_2S_3 through a Gooch asbestos filter, dry one hour at 255° C. and weigh.

Platinum in Dental Alloys, etc. Richards (*Analyst*, XXVII., 265). In alloys containing Pt and Ag only, it was found that HNO_3 dissolved

the Pt partially, and left some Ag undissolved whatever the proportions of Ag might be. Treatment with boiling conc. H_2SO_4 was found to be the only efficient method of separation, which had the merit of simplicity. This mode of attack is also applicable to Pt-Au-Ag alloys and Pt-Au-Ag-Sn alloy.

Platinum Metals, Detection. Leidie and Quinessen (*Bull. Soc. Chim.*, XXVII., 179). The metal in a find state of division (precipitated or as filings) is mixed with five to six times its weight of Na_2O_2 and gently heated up in a nickel crucible. Stir well when pasty, bring finally up to a semi-fluid consistency, cool, place in an evaporating dish, cover with a funnel and add ten to twelve times as much water as the Na_2O_2 used. After reaction, transfer to a tall beaker and allow to settle, decant, filter and wash. Os, Ru, Pd and Ir go into solution in combination with Na. The first three give yellow or orange solutions; Ir affords a blue solution. Pt and Rh remain insoluble in water together with the Ni_2O_3.

Passing a current of Cl through the (warmed) water solution carries OsO_4 and RuO_4 over into the distillate (leaving Pd and Ir). In this distillate KNO_2 or alcohol and KCl give red potassium osmite, K_2OsO_4. Alcohol and KCl afford black metallic Ru. The solution containing Pd and Ir on evaporation with KCl and a little HNO_3 affords *ruby* crystals of K_2PdCl_4 or *black* crystals of K_2IrO_4 or a mixture of the two, if both are present.

The portion insoluble in water is dissolved in HCl. After boiling off the excess of acid KNO_2 is added to neutrality, then Na_2CO_3; boil and filter off the NiO. Acidify with HCl. Rh, if present, shows at this point the rose color of $Na_6Rh_2Cl_8$. Evaporate to dryness, take up with water, and separate Pt by addition of KCl as K_2PtCl_6.

Gold and Silver in Pyrites. Buddeüs (*Chem. Ztg.*, XXIV., 922). Grind the ore fine enough to pass a sieve of 300 to 400 meshes per cm. Take 100 gms. or more according to richness and roast in a muffle, placing the ore in a crucible preferably of white Paris clay. After disappearance of SO_2 odor, cool, shake out into a large porcelain or glass vessel, and treat with 250 to 500 cc. of HCl (1:1). Let stand in a warm place for about an hour, then add as much HCl (diluted) as before and boil for some time. The residue is to all intents SiO_2, clay and Au + Ag. Filter and wash, dry the residue and fuse in a crucible in the muffle, with 50 to 100 gms. test lead, and 5 to 10 gms. borax. Instead of test lead one may use a mixture of equal parts $Pb(C_2H_3O_2)_2$ and NaOH.

Cupel the lead button obtained. Results are very concordant and higher than by the usual method.

Silver in the Residues from Distillation of Zinc. Sander (*Zts. Angew. Chem.*, XV., 32). These contain Pb, as well as 20 to 30 per cent. of C. The author makes a mixture of 80 parts KNO_3 and 20 parts Na_2O_2, and mixes 20 gms. of his sample with 50 gms. of the mixture, and throws it (3 or 4 gms. at a time) into a red hot crucible. When the violence of action moderates, the crucible is placed in the fire, and the ordinary assay fluxes are added with 10 gms. litharge. The lead button resulting is cupelled as usual.

Cuprous Thiocyanate, Effect of HCl. Van Name (*Am. Jour. Sci.*, XIII., 20). If only a slight excess of NH_4CNS is used the proportion of free HCl shou d be small (0.5 per cent. by volume). With a large excess of alkaline thiocyanate much more free HCl has no solvent action. It is always preferable to reduce the amount of free HCl by neutralizing with NH_4OH or $(NH_4)_2SO_3$.

Volumetric for Copper. Repiton (*Monit. Sci.*, XVI., 287). K_4FeCy, in tenth normal solution may be used on a boiling *neutral* solution containing the Cu as $CuSO_4$. The end reaction is when test drops begin to give blue with $FeSO_4$.

Another method is proposed by precipitation with a known amount of standard $H_2C_2O_4$, and titrating the excess by $K_2Mn_2O_8$ in the filtrate.

Volumetric for Copper. Guess (*J. Am. Chem. Soc.*, XXIV., 708.) The method is in use at the Silver Lake Mines, Colorado. It consists in precipitating as $Cu_2(CNS)_2$ treating the washed precipitate with hot NaOH, which affords $Cu_2(OH)_2$ and NaCNS, and titrating the latter in acidified solution with $K_2M_2O_8$. The details are as follows: Treat 1 to 5 gms. of ore with HNO_3 and HCl in a flask, adding a little H_2SO_4 to combine with Pb if present. Boil off the excess of acid, filter and wash well. Neutralize the filtrate with NH_4OH, and then add a few drops of dilute HCl. Reduce by adding Na_2SO_3 in excess, and then precipitate with KCNS in slight excess. Heat to boiling. let settle, wash by decantation a few times, then transfer to the filter (11 cm.) and wash thoroughly with hot wa er. Then treat the precipitate with a boiling solution of 10 per cent. NaOH, running the solution into the original precipitation flask. Repeat the application of NaOH, and then wash well with hot water, acidify the solution with H_2SO_4 and titrate (still warm) with standard $K_2Mn_2O_8$. The reaction is

$$10HCNS + 12KMnO_4 + 8H_2SO_4 = 6K_2SO_4 + 12MnSO_4 + 10HCN + 8H_2O.$$

Theoretically, multiplying the iron standard of the permanganate by 0.189 should give its value in Cu. On account of a slight solubility of the $Cu_2(CNS)_2$ in the reagents, 0.192 is a factor more nearly correct. The best way is to standardize on a sample of pure Cu treated in the same manner as the ore.

Bismuth in Ores. Warwick and Kyle (*Eng. and Min. Jour.*, April 13, 1901). The method consists in: (1) Decomposition by HNO_3, (2) precipitation as oxalate, (3) converting the normal to the basic oxalate by boiling with water, (4) titration with $K_2MN_2O_8$.

1. Treat 1 gm. of the pulverized ore with 5 to 10 cc. HNO_3 in a casserole—evaporate to dryness. Add 5 cc. HNO_3 and heat to effect solution, add 25 cc. H_2O transfer to a beaker and dilute to about 100 cc.

2. Add to the solution 5 gms. $(NH_4)_2C_2O_4$ and boil vigorously for five minutes, let settle a few moments and decant the clear solution through a filter.

3. Boil the precipitate with two successive lots of water (about 50 cc. each) decant through the filter first used. If the last filtrate is acid to litmus, repeat the boiling up, decanting, etc., until the filtrate is neutral.

4 Dissolve the precipitate on the filter with 2 to 5 cc. HCl (1 : 1) catching the solution in the beaker containing the oxalate precipitate. Wash twice with water. Warm to effect solution, and dilute to 250 cc.

5. Neutralize the solution with NH_4OH. Acidify with H_2SO_4 (1 : 4) adding an excess. Warm to 70° or over and titrate with standard $K_2Mn_2O_8$. The whole operation can be carried through in 30 to 40 minutes.

Copper, Lead, Antimony and Tin in Alloys. Rössing. Yellow ammonium sulphide invariably dissolves some CuS when the sulphides are treated with that reagent Colorless Na_2S affords a satisfactory separation. The Sn must be positively in stannic form.

Clarke's method for separating Su from Sb (precipitation of Sb_2S_8 by excess of H_2S in presence of $H_2C_2O_4$ in boiling solution) was found to be the best.

Mercury in Ores. Ehrmann and Slaus-Kantschieder (*Chem. Ztg.*, XXVI., 201). In the examination of Dalmatian ores containing a large proportion of barytes the method pursued consisted in heating with dilute HNO_3 until as much decomposition as possible had been effected — then adding three times the volume of conc. HCl and warming until the residue is light colored, and the odor of Cl is gone. Cool, filter and pass H_2S. Filter off the sulphides through asbestos in a porcelian Gooch. Treat the precipitate on the filter with a little HCl + Br. Wash well, expel the Br from the solution by a current of CO_2, and precipitate again by H_2S. Filter again through a weighed Gooch (asbestos bed), wash until free from Cl. Wash off members of the As group by use of warm, yellow $(NH_4)_2S$, wash out this reagent — then remove PbS and CuS by treating with HNO_3(1 : 3). Wash off adhering S by repeated use of conc. solution of Na_2SO_3, the wash with hot water, and dry the HgS at 100° for weighing. If much Pb is present, treat with $NH_4C_2H_3O_2$ after washing with HNO_3 to take out $PbSO_4$ which might remain. In other respects the management is the same.

Lead Peroxide in Minium. Liebig (*Zts. Angew. Chem.*, 1901, 528). Weigh out 0.5 gm. of the sample in an Erlenmeyer flask, add water, and then 25 cc. of N/10 $Na_2S_2O_3$, and then 10 cc. of 30 per cent. acetic. Shake well; when the mass goes into solution, add 10 cc. of a 10 per cent. KI solution, some ZnI_2 and starch and titrate the excess of $Na_2S_2O_3$ with N/10 I solution. The end reaction is the change in color of the PbI_2 from citron yellow to deep dirty yellow. The cc. I solution should be multiplied by 239 (mol. wt. of PbO_2) to get the amount of Pb_2 to which it compounds.

Red Lead. Szterkhers (*Am. Chim. Anat. Appl.*, VII., 214). Instead of $H_2C_2O_4$, the author uses a standardized solution of $NaNO_2$ of about 1 per cent. strength.

Add to 5 gms. of the sample 100 cc. water and 5.7 cc. pure HNO_3. Heat to complete the reaction, which should give $Pb(NO_3)_2$ with brown PbO_2. Cool to 50° and add gradually an excess of standard $NaNO_2$. The reaction is:

$$PbO_2 + 2HNO_3 + NaNO_2 = Pb(NO_3)_2 + NaNO_3 + H_2O.$$

The excess of $NaNO_2$ is then titrated back with standard $K_2MN_2O_8$.

Separation of Glucina Wyrouboff (*Bull. Soc. Chim.*, XXII, No. 14). The compound $Gl_2O_3 6(C_2O_3)3K_2O$, contains 9.5 per cent. Gl_2O_3 and dissolves only to the extent of 1.4 parts in 100 of water at 15° the solubility increasing but little with a rise in temperature.

In the analysis of emerald, etc., it suffices to decompose by fusion with KOH, eliminate SiO_2 in the usual manner, evaporate the solution of the chlorides to small bulk, and add a concentrated solution of KHC_2O_4. Allow to stand for some time when the salt above indicated will separate.

Separating Cerium. Meyer and Koss (*Ber.*, XXXV., 672). From CeO_2 salts boiling with acetates and H_2O_2 causes a complete separation of CeO_2. In presence of Di and La salts some of those elements come down with the precipitate, when $NaC_2H_3O_2$ is used. If $Mg(C_2H_3O_2)_2$ is used, the precipitate is nearly absolutely free from Di or La. The precipitate must be filtered and washed hot, as it redissolves to some extent on cooling.

Precipitation of Rare Earths. MacMichael (*J. Am. Chem. Soc.*, XXIV., 540).

Zr is precipitated by aniline, O-toluidine, xylidine, dimethyl and diethyl-aniline, benzylamine, pyridine, piperidine and quinoline.

Th precipitated by aniline, O-toluidine, xylidine, dimethyl- and diethyl-aniline, pyridine, piperidine and quinoline.

Ce precipitated by aniline, O-toluidine, diethyl-aniline, benzylamine pyridine and piperidine.

La, Nd and Pr are only precipitated by benzylamine and piperidine.

Hence one may separate:

Th and Zr from Nd by use of quinoline.
Th and Zr from La by use of aniline.
Th from La by use of quinoline.
Ce from Pr by use of O-toluidine.
Th from Pr by use of aniline.
Th from La and Pr by use of xylidine.

Precipitating Thoria. Kolb (*J. Pra. Rl. Chem.*, LXVI., 59). Aniline fulfils the condition of being more basic than thoria, and less so than the other cerite earths. (ZrO_2, however, is also precipitated by aniline.) The solution of nitrate or chloride is somewhat acidified with dilute HCl or HNO_3 then nearly neutralized by NH_4OH, heated to boiling and aniline run in a drop at a time with agitation until the liquid is distinctly turbid. (Any marked excess of the aniline should be avoided.) Then on heating and shaking the thorium separates. Dilute with warm water, and stand aside in a warm place. Wash by decantation, adding a little aniline to the wash water if it be found necessary. The precipitate may perhaps be colored by coloring matter of the aniline, but becomes white on ignition. If the higher oxides of iron or cerium are present, they should first be reduced by adding SO_2.

If the proportion of thoria is comparatively small to that of the other bases, re-solution and re-precipitation may be found necessary.

Thorium. Metzger (*J. Am. Chem. Soc.*, XXIV., 275). Fumaric acid precipitates Th completely from a solution containing 40 per cent. alcohol

in the cold. Traces of cerite metals may accompany the precipitate, which are removed by a second precipitation.

Thorium in Monazite Sand. Benz (*Zts. Angew. Chem.*, XV., 297). Mix 0.5 gm. with 0.5 gm. NaFl, and fuse cautiously with 10 gms. $K_2S_2O_7$ in a covered platinum crucible until evolution of gas has ceased. Then heat for 15 minutes over a good flame, extract with hot diluted HCl, decant and extract the residue by boiling with moderately strong HCl. Filter, nearly neutralize with NH_4OH avoiding the formation of a permanent cloud, boil and add 3 to 5 gms. $(NH_4)_2C_2O_4$ and stir vigorously. A moderate amount of free acid has no solvent effect. Allow to stand over night. Filter, transfer the precipitate to an evaporating dish, washing the filter into the dish with fairly strong HNO_3. Evaporate nearly to dryness, add a few cc. conc. HNO_3 (gr. 1.4) and then 20 cc. *fuming* acid. Heat on a water bath to convert the oxalates to nitrates. Evaporate to dryness, and again with water to remove all free acid, redissolve, filter, bringing the filtrate to about 100 cc. Add NH_4NO_3 warm to 60° or 80° C and precipitate Th_2O_5 by addition of H_2O_2. Ignite to ThO_2 and weigh. A minute amount of Ce may accompany the precipitate, which (if necessary) may be estimated by dissolving in HNO_3 and estimated colorimetrically by use of H_2O_2.

Vanadium Estimation. Williams (*J. S. C. I.*, XXI., 389). Treat 1 to 2 gms. of ore with about 6 cc. HNO_3. After complete decomposition evaporate to dryness, heat with 4 cc. H_2SO_4 until NO_2 fumes are gone, dilute with hot H_2O and boil, filter off $PbSO_4$, etc ; oxidize filtrate with 4 cc. HNO_3; boil well. If excess of acid should be used, make alkaline with NH_4OH, and re-acidify with dilute H_2SO_4. Cool to about 40°C. and titrate with N/10 $FeSO_4$ containing free H_2SO_4 (standardized by $K_2Cr_2O_7$ or $K_2Mn_2O_8$) using $K_6Fe_2Cy_{12}$ as indicator.

$$\text{Fe value of standard} \times 0.914 = \text{Vd}.$$

$$V_2O_5 + 2FeSO_4 + H_2SO_4 = V_2O_4 + Fe_2(SO_4)_3 + H_2O.$$

In the case of alloys, dissolve 0.5 gm. in aqua regia or HCl and KClO, evaporate to dryness, heat with 6 to 8 cc. H_2SO_4 (making sure to expel all HCl and chlorides which interfere) dilute, oxidize with HNO_3 and titrate as before.

As a check, the solution can be titrated with standard $K_2Mn_2O_8$; results are usually a trifle higher.

Tungsten in Ores. Bullnheimer (*Chem. Ztg.*, XXIV., 870). Fuse 1 to 2 gms. in a nickel crucible with 4 gms. Na_2O_2 and 3 gms. NaOH. After solidification, the crucible while still hot is placed in water and the solution transferred to a 250 cc. flask. If any green of Na_2MnO_4 appears, add a little H_2O_2, cool, dilute to the mark and filter off 125 cc.; add 20 gms. NH_4NO_3. This affords $NaNO_3$ and excess of NH_4OH. Allow to stand to precipitate SiO_2 and SnO_2. When *these have completely separated* add $Mg(NO_3)_2$ to precipitate As_2O_5 and P_2O_5, let stand 6 to 12 hours and filter; acidify with HNO_3 and precipitate out WO_3 by use of $HgNO_3$. Filter, wash with water containing $HgNO_3$, dry and ignite to *constant weight.* If MoO_3 is present, it will be in the precipitate and is but slowly volatilized off. Its volatilization is facili-

tated by adding NH_4Cl and igniting. If the SiO_2 and SnO_2 are not completely precipitated before adding $Mg(NO_3)_2$ some WO_3 will appear in the precipitate. Nitrate reagents are used because of the final use of $HgNO_3$.

The $HgNO_3$ reagent is prepared by dissolving 200 gms. by warming with 20 cc. HNO_3 and some water, then dilute to 1 liter and add some Hg. After some hours, add NH_4OH until the solution is only faintly acid; allow to stand until the supernatant solution is absolutely clear, filter and ignite to WO_3, weigh, etc.

Molybdenum Steel. Kopp (*J. Am. Chem. Soc.*, XXIV., 186). Dissolve 0.5 gm. in a platinum crucible by use of 2 cc. H_2SO_4 (gr. 1.58) and 12 cc. water, evaporate off the water, add 30 gms. $KHSO_4$ and fuse. Dissolve in water and dilute to 500 cc., digest hot until clear, add 100 cc. NH_4OH and make up to 1 liter. Mix well, filter off 500 cc. through a dry filter, add 40 cc. H_2SO_4, run through a reductor (column of zinc granules) add 10 cc. H_2SO_4 and titrate with standard $K_2Mn_2O_8$.

To correct for impurities of the Zn, run a "blank" solution through the reductor consisting of 450 cc. water, 50 cc. NH_4OH, and 40 cc. H_2SO_4. *Ferromolybdenum* is managed in the same manner, except that the first attack is made by 15 cc. strong HNO_3, which is followed by the treatment with H_2SO_4, fusion with $KHSO_4$, etc.

A similar method is applied to tungsten steels, the 1 gm. sample being first dissolved in HNO_3, with final addition of HCl, evaporating to dryness to render SiO_2 and WO_3 insoluble, diluting, filtering and proceeding as above.

Molybdenum in Steel. Auchy (*J. Am. Chem. Soc.*, XXIV., 273). Treat not over 1.308 gm. of the sample with excess of strong HNO_3 and a little $KClO_3$. Boil down, add HCl and evaporate to dryness to remove SiO_2. Again take up with HCl and evaporate to appearance of scum. Then add 5 cc. HCl with 15 cc. water and heat until dissolved. Dilute to 50 cc. and pour slowly into 20 gms. NaOH dissolved in 100 cc. water in a 300 cc. flask. Dilute to the mark, mix well, let settle and filter off 250 cc. Place this in a beaker, add H_2SO_4, boil down to less than 100 c., reduce with Zn and titrate with standard $K_2Mn_2O_8$.

Selenium in Sulphuric Acid. Jouve (*Bull. Soc. Chim.*, XXV., 489). Crude acetylene when passed into the acid gives a red coloration if Se is present. The coloration occurs more promptly in the presence of HCl vapors; 1 in 100,000 may be thus detected.

Volumetric for Selenium. Friederich (*Zts. Angew. Chem.*, XV., 852). The method depends on the reaction of precipitated Se on $AgNO_3$ in ammoniacal solution. Thus: $AgNO_3 + 3Se + 3H_2O = 2Ag_2Se + H_2SeO_3 + 4HNO_3$. The precipitate and filter, after thorough washing, are placed in the beaker in which the precipitation was effected, and 10 cc. of NH_4OH and (say) 25 cc. N/10 $AgNO_3$ added. After two to three minutes, boiling the red Se should be changed to black Ag_2Se, and white Ag_2SeO_3 should precipitate against the glass. If the latter does not appear either Se is very small or $AgNO_3$ is deficient. To make sure add more $AgNO_3$ solution, also NH_4OH, and boil again. Then acidify with

HNO_3 of about three per cent. and titrate back excess of Ag by standard NH_4CNS. If Se is over 0.05 gm. the precipitate is agglomerated in too large clots to give the best results.

Sulphur in Irons. Dougherty (*Iron Age*, May 8, 1902). The evolution method has been found to be capable of giving accurate results if the portion of the sample taken for the purpose, is previously ignited in a porcelain crucible covered with a disc of filter paper. The H_2S evolved is passed in to KOH and titrated with standard I. Elliott method.

Sulphur in Pig Iron. Stehman (*J. Am. Chem. Soc.*, XXIV., 644). The Eschka method was applied thus: The samples were pulverized until they would pass a 50-mesh sieve or finer. If the material was coarser incomplete oxidation was found to be inevitable. A mixture was made of MgO four parts, K_2CO_3 one part, Na_2CO_3 one part.

3 gms. of the prepared sample were mixed with 3 gms. of the basic mixture. About 0.5 of the latter was reserved to be applied as a cover to the charge. The material was charged in a 30 cc. platinum crucible set in a hole in an asbestos board. The bottom of the crucible was then heated to full red for one hour. When cold, the mass was detached from the crucible, treated with hot water and 10 cc pure water added. Boil 13 minutes and filter. Acidify the filtrate with HCl, boil out Br and precipitate with $BaCl_2$. The results show good agreement with other methods (Bambers, etc.).

Sulphur in Coal. Stoddart (*J. Am Chem. Soc.*, XXIV., 852) Sixteen different coals from various localities (American) were examined by six different methods. The results indicated that Eschka's method is the best, provided the solution is evaporated down to remove SiO_2 before precipitating by $BaCl_2$.

Sulphur in Plants. Fraps (*J. Am. Chem. Soc.*, XXIV., 344). Heat 5 gms. with conc. HNO_3 on a water bath, eventually concentrating to small bulk, then add 10 cc. of 5 per cent. solution of KNO_3, evaporate to dryness and ignite until whit . Dissolve in HCl, evaporate to separate SiO_2 and determine by $BaCl_2$ as usual. Results by this method are perceptibly higher than by the usual method.

Persulphates. Peters and Moody (*Zts. anorg. Chem.*, XXIX.. 326). Comparison of Methods. *Leblanc and Eckardt.* Treating with excess of standard $(NH_4)_2Fe(SO_4)_2$ for 10 minutes at 60–80° or for even hours at ordinary temperatures, and titrating excess of ferrous iron by standard $K_2Mn_2O_6$. Results accurate. Filling the flask with CO_2 was found to be unnecessary.

Grützner. Reducing by standard solution of As_2O_3 in boiling KOH or NaOH solution, cooling, acidulating with H_2SO_4, adding $KHCO_3$ and titrating excess of AS_2O_3 with standard I. Results good, provided correction is made for oxidizing reaction produced by the reagents used.

Mondolfo. Heating in a closed flask for a short time at 60 to 80° with KI and titrating the liberated I with standard $Na_2S_2O_3$. Results usually low unless the volume is kept small, and the time of heating increased to thirty minutes.

Namias. Same as the last except that the mixture is allowed to stand for several hours at ordinary temperatures. Results also low with the exception as noted.

Gooch and Smith's method for chl rates was also applied to persulphates with good results. It consists in adding a standard solution of KI in excess, also an excess of K_3AsO_4, acidifying with H_2SO_4, dilu ing, and boiling down to one third of the original bulk, after cooling rendering alkaline with $KHCO_3$, and the remaining arsenite titrated with standard I solution.

Standardizing for Titration of Phosphates. Muller (*Bull. Soc. Chim.*, XXV). $Na_2HPO_4 \cdot 2\ H_2O$ is objectionable because so easily efflorescent. The "Phosphorus Salt" $NaNH_4HPO_4.H_2O$ is much superior, losing only 0.15 per cent. of its weight under conditions where the first-named salt loses 2.4 per cent. Crystallized dicalcic phosphate—$Ca_2H_2(PO_4)_2.4H_2O$—is superi r to either, not altering at all under ordinary atmospheric conditions. To prepare it add a cold dilute solution of Na_2HPO_4 to dilute $CaCl_2$ solution until almost complete precipitation is effected. The precipitate is at first gelatinous, but quickly b comes crystalline. It is easily washed, after which dry on flat plates at 70° C. The theoretical content in P_2O_5 is 41.27 per cent. The material prepared by the author appeared to c ntain 0.1 to 0.2 more.

Boric acid. Farnsteiner (*Zts. Nahr. Genussm.*, V, 1). The acid may be accurately titrated with N/2 KOH, NaOH or $Ba(OH)_2$ (with phenolphthalein indicator), when both are dissolved in absolute methyl alcohol. The end reaction cannot be asser ed until the coloration is very marked, as a faint pink will show before the neutralization is c mplete. The distillate obtained by distilling Bo_2O_8 with methyl alcohol can be almost as readily titrated as the solution of B_2O_8 in methyl alcohol.

Hebebrand (*ib.*, V., 55) proposes a colorimetric method. Render the solution slightly alkaline with NaOH, evaporate in a platinum dish and ignite to destroy all carbonaceous matter. Then dissolve in 5 cc. of water containing 0.5 cc. HCl, pouring the solution into a comparison tube. Rinse the dish into the tube with 15 cc. of alcohol, add 15 cc. HCl (sp. gr. 1.12) and after cooling 0.2 cc. of a 1 per cent. solution of turmeric. Compare with the results obtained by subjecting known amounts of H_3BO_3 to the same treatment, allow to stand 30 minutes before comparing. 0. mg. B_2O_8 gives a pale brown, 10 mg. a bright rose red .The color is destroyed by boiling or by prolonged exposure to light.

Silica Determinations. Hillebrand (*J. Am. Chem. Soc.*, XXIV., 362). Experiments here detailed show that repeated evaporations with HCl followed by a single filtration do not entirely remove SiO_2 after the usual fusion with alkaline salts, carbonates, etc. Two or more evaporations alternating with filtrations are necessary.

The SiO_2 passing into the filtrate is not (as is usually supposed) wholly thrown down by NH_4OH or $NaC_2H_3O_2$ precipitation of iron, alumina, etc.

SiO_2 is appreciably soluble in fused $KHSO_4$.

To obtain the correct weight of the SiO_2 separated, ignition by the blast is absolutely essential.

Silicon in Ferro Silicon. Morris (*J. S. C.*, LXXI., 537). The ordinary mode of decomposing is by fusion with Na_2CO_3. The author has found that many of the inconveniences of this method may be obviated by attacking 0 5 gm. of the sample with 10 gms. Fe_2Cl_6 (U. S. P.) 50 cc. conc. HCl and 0.5 gm. tartaric acid. But little heating is necessary to effect solution. When the solution is complete add 25 cc. conc. HCl, boil for a few moments, remove the heat, dilute with cold water and filter, washing with hot dilute HCl and hot water.

Silicon in Ferro Silicons. Ramorino (*Monit Sci.*, XVI., Jan., 1902). Na_2O_2 fused with ferro silicon affords an almost explosive action. If, however, it is moderated by mixing 0.5 gm. of the sample with 10 gms. of mixed Na_2CO_3 and K_2CO_3 and 1 gm. Na_2O_2, by careful heating in platinum crucibles. the action can be controlled, and decomposition readily and quickly effected. Dissolve, add 10 cc. HNO_3 and 2 gms. $KClO_3$ as well as dilute HCl — evaporate to dryness, etc., and determine SiO_2 in the usual manner.

Silicon in Aluminum. Goldschmidt (*Zts f. Elecktrochem.*, VIII., 123). In dissolving in HCl for separation of SiO_2 some Si is lost as SiH_4. This source of error is obviated by adding Br to the HCl used to effect solution.

Graphite in Irons. Dougherty (*Iron Age*, May 8, 1902). Treat 1 gm. of drillings with 60 cc. HNO_3 (gr. 1.13). Heat until no more nitrous fumes come off (about 30 minutes), then boil hard 5 minutes. Weigh a Gooch crucible and filter paper cut to fit the bottom Stir the liquid and filter. Then wash, once with dilute HNO_3, thrice with hot water, twice with hot KOH solution (10 to 15 per cent.) thrice with hot water, once with alcohol, and once with ether. Dry one hour at 115°C., weigh, ignite until nothing black remains, weigh again. First weight increase over weight of crucible and paper disc = graphite + silica, etc.

Second weight increase over weight of crucible = silica, Difference × 0.96 = graphite.

Asbestos for the filter is not desirable, as it shows a constant loss of weight on ignition.

Cyanide — Detection in Presence of Thiocyanate and Ferro and Ferricyanides. Preiss (*Am. Chem. Jour.*, XXVIII., 240).

Remove heavy metals, etc., by boiling 25 to 50 cc. of the solution with alkaline carbonate convert ferricyanides to ferro—by adding KOH and about 0.5 gm. Al. filings; when this is complete as ascertained by testing a few drops with $FeSO_4$, acidify with HCl and precipitate out all ferrocyanide with excess of $HgCl_2$. Shake well (do not heat) and filter pouring the liquid back upon the filter until it runs clear. Then convert the HCy present into ferrocyanide by adding KOH, filtering off HgO, then to the filtrate $FeSO_4$ and boiling. Filter, acidify the filtrate with HCl, and add Fe_2Cl_6. Add $HgCl_2$ to decolorize the thiocyanate, when the prussian blue color will be perceived if the original solution contained HCy. Except where specified, all solutions should be kept cold.

Titration of Cyanide and Chloride. Gatehouse (*Chem. News*, LXXXIV., 197). On adding standard $AgNO_3$ solution to a solution containing both cyanide and chloride, the cyanide reacts first (to all intents).

Thus: adding $AgNO_3$ to the first appearance of permanent turbidity, determine CN (or KCN) present, KCN.AgCN being formed. Addition of as much $AgNO_3$ as before affords AgCN as a precipitate, then addition of K_2CrO_4 and continuing the addition of $AgNO_3$ gives the ordinary end-reaction when all of the chloride has been converted to AgCl.

Stability Tests for Nitro Explosives, etc. Aspinwall (*J. Sci.*, XXI., 687). Nitro explosives must meet these conditions:

1. Unchangeability under variation of temperature between + 45° C. and — 30° C.
2. Not affected by moisture.
3. Ballistic properties must be unchanged under these conditions.
4. Not liable to spontaneous decomposition or disintegration.

KI Test. Evolution of gases affecting *moistened* paper (KI solution). The British government specifications are: The fumes shall not give a brown line of demarcation between the wet and dry portions of the paper before the time specified.

Description.	Temperature.	Time.
Nitro glycerine and dynamite,	160° F. = 71° C.	15 minutes.
Blasting gelatin, gelatin dynamite, etc.,	160° F. = 71° C.	10 "
Cordite and ballistite,	180° F. = 82° C.	15 "
Gun cotton, tonite, etc.,	170° F. = 76.6° C.	10 "
Gelatinized gun-cotton preparations,	180° F. = 82° C.	15 "

U. S. specifications:

Description.	Temperature.	Time.
Smokeless powder,	100° C.	10 minutes.
Nitro cellulose	65.5° C.	30 "

The author does not regard the test as satisfactorily indicative of the stability of the explosive.

Guttmann proposed the use of diphenylamine instead of KI. With that reagent many have failed to obtain concordant results.

Hotsema proposed heating the explosive in a constant bath for a certain length of time and then flowing dry CO_2 through it, the gas being passed through glass wool moistened with H_2SO_4 and diphenylamine. The method has never received official recognition.

The *Thomas test* consists in heating a portion of the sample in a cylinder 16 cm. high and 1.5 cm. diameter with ground glass stopper for eight hours a day in an oil bath maintained at a certain temperature (100° C.). The exact time of appearance of brown fumes is noted as the end of the test. A powder containing nitroglycerine should evolve no brown fumes at 94° to 96° C. in four days, or nitrocellulose powders at 99° to 101° C. in three days. The length of time required for the test is objectionable.

The *Vielle test* is somewhat similar. The tubes containing the samples are closed to all intents hermetically by means of a spring and rubber gasket on the cover. The heating is maintained by a bath at 110°. A piece of blue litmus paper is placed in contact with the explosive, when that is reddened completely, the time is noted, a fresh piece of blue litmus paper

is placed in the tube and the heating continued. This is repeated until the litmus paper is completely reddened within one hour. The aggregate of the times taken for the changes in the color of the litmus papers is taken as the indication of the stability of the explosive.

The *Will test* consists in heating the dampened explosive in a tube at 135° and measuring the N evolved in the gases given off. A current of CO_2 is kept passing through the tube to sweep out all the gases evolved, which are passed through a suitably arranged combustion tube to convert all the nitrogen oxides to N. The CO_2 is absorbed, and the volume of N is read off, first at the end of 30 minutes, and afterward at intervals of 15 minutes. If the gas is given off at a fairly uniform rate, the indication is that the nitro substance has been suitably purified. Dr. Ries proposes to modify this test by heating in vacuo instead of in a current of CO_2.

Ozone Paper. Chlopin (*Zts. Nahr. u. Genussm*, V., 504). Paper impregnated with the dye known in the trade as Ursol D when moistened, turns blue if ozone is present. H_2O_2 has no effect. Nitrous fumes, Cl and Br give a bluish-green, passing into yellow.

Hydrogen Peroxide. Arth (*Monit Sci.*, XV., No. 715). Oxalic acid is present in some commercial H_2O_2. A method proposed for its detection (and determination) is to add to a measured volume of the sample, NH_4OH until alkaline, and then $CaCl_2$—to dissolve the precipitate in H_2SO_4 and titrate warm with standard $K_2Mn_2O_8$. This involves some error, as the precipitate may consist partially (or even entirely) of the slowly soluble CaO_2. $H_2C_2O_4$ in a solution of H_2O_2 rapidly diminishes its strength.

Attention is called to the practice of many manufacturers who use a solution of $K_2Mn_2O_8$ containing 3.163 gms. of the salt per liter. They operate on 2 cc. of the sample and the number of cc. of $K_2Mn_2O_8$ solution used, divided by 3 is taken as the volume value of the sample. In fact the results only indicate actually 83.8 per cent. of what is claimed for it. In other words, what by this test would be asserted to be a 10 volume solution is really only 8.38 volumes.

ALUMNI AND UNIVERSITY NEWS.

SCHOOL OF CHEMISTRY.

GENERAL.—Chemistry was included for the first time last year in the summer session of the University which lasted for six weeks, beginning July 7. The following courses were given by Professor Miller, Dr. Jouët and Dr. Chambers.

General Chemistry.—An elementary course equivalent to the entrance requirements now in force in the schools of applied science.

The Teachers' Course in Chemistry, arranged especially to meet the needs of those teaching chemistry in high schools.

Qualitative Analysis.—The equivalent of the regular first-year course.

Quantitative Analysis.—A short course less technical than the applied science courses.

The quantitative laboratory was also open to special students who did not wish to take any of the regular courses.

The number of students attending these courses was fifty-nine and the work done was most satisfactory.

The death of one of the officers of the department, Mr. G. C. Hubbard, occurred last May, after an operation for appendicitis. Mr. Hubbard was a graduate of the School of Chemistry in 1901 and was assistant in assaying up to the time of his death, having charge of the practical work of the assay laboratory. His sudden death was a great shock and the cause of sincere regret to the department.

The present academic year finds this Department of the University in a very flourishing condition as to officers and students, both in numbers and in quality, but very much handicapped, if not indeed crippled, by the overcrowded condition of the laboratories.

General and Applied Chemistry. — The school has suffered a severe loss this year in the absence of Mr. Milton C. Whitaker, tutor in chemistry for the last four years, who resigned to take the responsible and important position of chemist to the Welsbach Light Company, of Gloucester City, N. J. Mr. Whitaker, during his stay at Columbia, had made himself universally popular with both his colleagues and the students, and, before his departure in June last, at a meeting of the Columbia University Chemical Society at the house of Professor Chandler, a handsome silver tea service, suitably engraved, was presented to him as a token of friendship and esteem from his many friends at Columbia.

The laboratory course in General Chemistry for Columbia College students, known as Chemistry 1. formerly given by Mr. Whitaker, has been changed to a new course, Chemistry 6, consisting of both lectures and laboratory work in elementary chemistry. This is intended to serve as an equivalent to the entrance examination in chemistry, and is

required as a prerequisite to Professor Chandler's course of Chemistry 1, from all students who have not covered sa isfactorily the same ground in their previous work This course is given by Dr. Carl Ernst, B.S. Northwestern University, 1890, Ph.D. Leipzig, 1900, who has succeeded Mr. Whitaker as tutor in chemistry. It has proved extremely attractive to the college men, for whom it is intended, and has been elected, so far, by 64 students.

Another course, Chemistry 10, on advanced inorganic chemistry, including the rare elements formerly given by Mr. Whitaker, has been taken this year by Professor Pellew. This course has now been made compulsory for all third year regular students in the School of Chemistry, but as an elective was taken last year by all the second year regular students, who are therefore excused from attendance this year. It is, however, being taken by 8 students, either post-graduates or advanced standing men.

The classes in Professor Chandler's lectures are unusually large, Chemistry 1 having on its rolls 198 students, which, with the college men under Dr. Ernst, make a total of over 260 men studying general chemistry this year, as compared with 205 last year.

Chemistry 24, Industrial Chemistry, General Course, is almost equally popular with 185 students as against 147 men last year

Fortunately, when Havemeyer Hall was planned, the probability of large classes was duly recogn zed, and the main chemical lecture room was accordingly made the largest of any lecture room in the University. But if the classes continue to increase in the present proportions it will be impossible to accomodate them even in the lecture room. The labo atories, as is seen below, are crowded at present almost beyond endurance.

In tustrial Chemistry. — The various courses given in this laboratory are all attracting their fair proportion of special students and post-graduate students.

Although the regular students of the School of Chemistry have not yet begun their work there, instruction is now being given in each of the three courses, inorganic preparations, dyeing and calico printing and electro-chemistry, to classes of four to six students. The course in electro-chemistry has proven decidedly attractive, and is being taken this term, as an extra, by two regular fourth-year students of the analytical option, as well as by two electrical engineers and two post-graduates. In anticipation of the crush which will take place next term, the capacity of the Electro-chemical Laboratory has been doubled, and its equipment improved until now it provides every facility both for regular instruction and for research work in this important branch of chemistry.

The Qualitative Laboratory is so crowded this year that no suitable room could be found t ere for Dr Ernst, and so he has been invited to occupy room 418, Havemeyer, in the Industrial Laboratory, a room hitherto devoted to r se rch work. Mr. Tucker and Dr. Ernst have begun a careful investigation on the subject of obtaining electrical energy from the oxidization of carbon and of carbon monoxide. with especial reference to the work of Dr. Borcher's on this subject published some little time ago.

Physical Chemistry.—The work in this department has assumed such proportions that th services of an assistant has been found necessary, and Mr. Henry A. Jackson, B.S. (Princeton, '99), has received the appointment. As Mr. Jackson has had a year in Leipzig, under O twald, he is very well fitted for the position This year there are six post graduate students, candidates for the degree of Ph.D , three taking the subject as a major, and three as a minor; and twenty-five undergraduates. From this year on the fourth-year metallurgists are to take chemistry (4) with the chemists as a required subject, it having been found very necessary in the study of the new metallurgy. Professor Morgan is giving during the first term an optional course on electro-chemistry to the electrical engineers, which will probably become a required course next year.

As a great amount of the work necessary for the organization of the department under the new conditions is now completed, it is expected that much original work will be published this year, as four investigations have already been started and several others are about to start. The second edition of Professo Morgan's "Elements of Physical Chemistry" appeared in the spring a d is being used as the basis of the lecture course (Chemistry 4). The problems given in the last chapter of this work to illustrate the text have proved very successful in practice, and these and other new ones are being used in the quiz work, so that the student learns first the facts, and then how to apply them in practical work.

Organic Chemistry —During the past year a number of changes have been made in the courses in this subject.

In order more satisfactorily to prepare chemical students for the industrial chemistry and proximate organic analysis of the third year, elemenmentary organic chemistry (Chem. 20) has been made a required subject for all second-year chemists. The course heretofore given to third-year chemists has been transferred to the fourth year and consolidated with the regular fourth-year course to a single course (Chem. 35) of five hours per week throughout the year. The general laboratory work (Chem. 33) has been set off from the lectures as a separate course, to permit of its being elected by those who are already sufficiently well trained in the theoretical part of the subject. The conferences (Chem. 36) are now required of all students taking the organic option, and of those who, as candidates for higher degrees, take major coures in organic chemistry A new advanced course is offered this year at Barnard by Dr. Chambers, and already several students have registered for it.

The progress of the department has been greatly aided and stimulated by the recent action of the trustees in advancing the grade of the associate from assistant to that of tutor, thus making it possible to retain an experienced man and steadily develop the work without the interruption consequent upon the breaking in of new men every year.

From the present outlook, the total enrollment in the various courses will exceed that of any previous year. It is an encouraging sign that there appears to be a steady and quite rapid increase in the number of those who elect the elementary courses, their value being well recognized by seniors in the college who expect to enter the Medical Department.

Professor Bogert has recently been elected a Vice-President of the Society of Chemical Industry (of England).

During the calendar year 1901 the following publications appeared from the Organic Laboratory:

1. "Some Experiments with the Mononitroorthophthalic Acids." By M. T. Bogert and L. Boroschek; *J. Am. Chem. Soc.*, 23, 740.
2. "Review of V. Thomas's 'Les Plantes Tinctoriales et leurs Principes Colorants.'" By M. T. Bogert; *Science*, N. S., 14, 218.
3. "Review of V. Thomas's 'Les Matières Colorantes Naturelles.'" By M. T. Bogert; *Science*, N. S., 14, 846.
4. "The New Radio-Active Substances." By C. E. Caspari; *Am. Chem. J.*, 25, 77.
5. "The Synthesis of Amines by the use of Alkyl Salicylates." By A. Tingle; *Am. Chem. J.*, 25, 144.
6. "The Higher Superoxides of Hydrogen." By C. E. Caspari; *Am. Chem. J.*, 25, 336.
7. "Antipyrin and its Derivatives." By D. C. Eccles; *S. of M. Q.*, 22, 259.
8. "The Density and Molecular Weight of Ozone." By C. E. Caspari; *Am. Chem. J.*, 25, 432.
9. "The Synthesis of Alkylketodihydroquinazolines from Anthranilic Acid." By A. H. Gotthelf; *Jour. Am. Chem. Soc.*, 23, 611.

The following investigations are now in progress:

1. "Pentadiazenons." By M. T. Bogert.
2. "The Exchange of Cyanogen for Other Groups." By M. T. Bogert.
3. "The Chlorides of the Mononitroorthophthalic Acids." By V. J. Chambers.
4. "Reactions with Betasulphopropionic Acid." By V. J. Chambers.
5. "The Synthesis of Methyl Quinazolones." By H. St. J. Hyde.
6. "An Investigation of Metaminobenzonitrile." By H. T. Beans.
7. "The Synthesis of Ethyl Dioxide." By Mr. Beatty.

Quantitative Analysis and Assaying.—The crowded condition of the quantitative and assay laboratories is worse than ever before. In quantitative, every desk is taken and it is only possible to do any thesis work by utilizing the rooms of the instructors, and during the second half year a portion of the organic laboratory. In assaying, the class taking the course during the first half year is so large that it had to be divided into two sections, which work alternately. This has made it necessary to keep the laboratory open every week day and to curtail somewhat the practical work.

The large section of mining engineers will also be divided for their recitations in quantitative analysis.

The changes in the staff have been: Mr. Everett J. Hall, formerly assistant in metallurgy, appointed to the recently created tutorship in assaying.

Mr. J. L. Danziger appointed assistant in analytical chemistry (quantitative) in place of Dr. Alfred Tingle resigned.

Of those who received doctors' degrees in chemistry last year:

Dr. L. A. Youtz is now professor of chemistry at Lawrence University, Appleton, Wisconsin.

Dr. F. J. Metzger is private assistant to Professor Chandler.

Dr. C. J. Pretzfeld is with the National Electrolytic Company at Niagara Falls.

Of the researches reported in progress last January, the following have been published: on "The Determination of Lead in Ores," by Irving C. Bull, SCHOOL OF MINES QUARTERLY, June, 1902; "A New Separation of Thorium from Cerium Lanthanum and Didymium and its Application to the Aanalysis of Monazite," by F. J. Metzger, *J. Am. Chem. Soc.*, October, 1902; on "The Determination of Sulphur in Coal," by C. W. Stoddart, *J. Am. Chem.Soc.*, Sept., 1902; "The Composition of the Ferrocyanides of Zinc," by E. H. Miller and J. L. Danziger, *J. Am. Chem. Soc.*, Sept 1902; "A New Qualitative Test for Cobalt, by J. L. Danziger, *J. Am. Chem. Soc.*, June 1902; and *Zeitschrift für anorganische Chemie*, Vol. 32, p. 78; on "The Composition of the Ferrocyanides of Manganese," by A. E. Dickie, *J. Am. Chem. Soc.*, Oct., 1902; on "The Relation of the Heat of Combustion to the Specific Gravity in Fatty Acids," by H. C. Sherman and J. F. Snell, *J. Am. Chem. Soc.*, April, 1902.

The following articles will soon appear in the *Journal of the American Chemical Society:* "The Determination of Sulphur and Phosphorus in Organic Materials," by H. C. Sherman; on "The Composition of Cows' Milk," by H. C. Sherman

The number of undergraduate students in analytical chemistry is larger than ever before, and includes many new men from institutions all over the world who enter with advanced standing. The opening of the qualitative and quantitative laboratories in the summer session is of great assistance to these men, many of whom are behind in their chemistry, as it gives an opportunity to make up their laboratory work without interfering with the afternoon work of the regular session.

The demands for our graduates continues to be good—far greater than the supply.

THE COLUMBIA UNIVERSITY CHEMICAL SOCIETY.

The society held its first meeting, for the present year, on the afternoon of October 29th, in Havemeyer Hall, and elected the following officers: *Honorary President*, Prof. C. F. Chandler; *Honorary Vice-President*, Prof. C. E. Pellew; *President*, Gail Mersereau, '03 S.; *Vice-President*, S. Gaulbrandsen, '03 S.; *Secretary*, J. E. Goodell, P. G.; *Treasurer*, G. V Williamson, '03 S.; *Executive Committee*, H. T. Beans P. G, C. H. Dempwolff, '03 S., H. N. Cox, '04 S., A. W. Hahn, '05 S., C. G. Fink, '03 Columbia College.

A committee consisting of the officers of the society was appointed to draw up a new constitution and present it at the next regular meeting, and the Executive Committee were authorized to arrange, at an early date, for a dinner.

DEPARTMENT OF MINING.

The summer class in mining was held in June and July in the silver-lead mines of Park City, Utah. To make final arrangements before the arrival of the students, Adjunct-Professor Peele, accompanied by Instructor Kurtz, left New York on May 26th, and on the 31st reached Park City, where they were joined by Mr. J. F. McClelland. Mr. McClelland, who during the past two years has been instructor in mining at the University of Wyoming, and has also been engaged in field work in California, was

appointed last spring lecturer in our department. He took charge of the mine surveying of the class, while Mr. Kurtz assisted in the general underground and surface work

On June 5th the class arrived at the mines. It consisted of twenty-two students, viz.: Messrs. Aplington, Baldwin, Bauchelle, Brady, Bowles, Cabot, Caetani, Constant, Gunther, W. H. Hendrickson, Holt, Judd, Knoblauch, W. H. Landers, Law, Lovejoy, Morrell, R. T. Pelton, Stillwell, Shaw, Schmidt and Wichman.

The usual detail work, together with the surveying, was done in the well-known Daly West silver mine, by kind permission of the president of the company, Mr. J. E Bamberger. This work occupied about four weeks, after which visits of a couple of days each were made to the neighboring Ontario and Silver King mines. Before leaving Park City, the class also visited, with Mr. Bradley Stoughton, the Marsac lixiviation mill, formerly operated by the Daly Mining Co

The Daly West mine is situated two miles from Park City, at an altitude of 8,000 feet above sea level and over 1,200 feet higher than the town. It contains two lead-silver veins: a contact dipping 20°, between limestone and quartzite, and a so-called fissure vein, dipping from 65° to 70°. The latter appears to be the result of deposition in a fault plane, since the limestone has been thrown downward on the hanging wall side a vertical distance of about 600 feet. A fault, dipping 65°, also occurs in the contact vein, throwing it upward some 70 feet. Along this fault a number of large ore-bodies have been found, several of them requiring square set timbering. Generally, where undisturbed, the contact vein ranges from 4 to 8 feet thick, and is timbered with ordinary stulls. Extending over considerable areas, the ore of the contact is split into an upper and lower floor, separated by a few feet of barren or nearly barren limestone, sometimes accompanied by strata of quartzite. Passing down through the limestone into the main or Ontario quartzite, a number of small fissures are found. These, though nearly normal to the dip of the contact are called "verticals," and at their intersection with the contact, local enrichment of the ore is frequently noted. The contact vein appears to be a remarkably persistent ore carrier. Its apex occurs in the Quincy mine—recently acquired by the Daly West Company—some 1,500 feet southeast of the Daly West shaft, and it is probably identical with the contact which has been extensively and very successfully developed in the Silver King mine, 6,000 feet to the northwest. In the Daly West it has, thus far, been the source of the greater part of the output and now contains large quantities of ore opened up for extraction.

Hitherto the mine has been worked through a single shaft, with two hoisting compartments, though connection is about to be made with the Quincy. The contact vein has been developed from the 900-foot level of the shaft, the lower levels—at 1200 and 1400 feet—being on the fissure vein. Though the bottom of the shaft is at the 1400-foot level, another level, 1550 feet deep, has been opened on the fissure from an inclined winze. At the 1200-foot level, there is a tunnel, about 2¼ miles long, passing through the workings of the old Daly and Ontario mines to the railroad station in Park City. This tunnel is used for haulage of ore, concentrates, coal and powder. The mill concentrates are lowered in cars, or shot down through an iron pipe to the tunnel level, whence they

are hauled out by mules in trains of mine cars. Coal and powder are brought in on the return trips. Without rehandling, the cars of coal are then hoisted in the shaft and dumped into the bins at the boiler house. Formerly, the powder was stored in magazines on the 1200-foot level, but since the disastrous explosion in July last it is hoisted to the surface. All the first-class ore from the 900-foot level workings is shot down through a rock chute close to the shaft to the 1200-foot level, and is hauled out with the concentrates to the railroad. Only the mill ore and waste is hoisted to the surface. The mine workings proper aggregate a number of miles in length.

The ore consists mainly of galena, blende, pyrite and chalcopyrite, with some grey copper and lead carbonate, the latter being generally found on or near the foot wall of the contact vein. Considerable sorting is done underground, producing a first-class or shipping ore containing 58 to 60 ounces silver, 20 to 25 per cent. lead, 2 to 2½ per cent. copper, 18 to 19 per cent. zinc and $1.00 gold.

Situated close to the shaft is the concentrating mill, which contains crusher, rolls, trommels, jigs, Huntington mills, classifiers, settlers, Wilfley tables and slime tanks. It treats very successfully about 6,000 tons of ore per month, producing 1,400 to 1,500 tons of concentrates.

The visits made to the Silver King and Ontario mines were most interesting ones. At the first mentioned mine we found an unusually fine surface plant, comprising a large and elaborate automatic sampling works, a concentrating mill and a Finlayson wire-rope tramway for conveying first-class ore and concentrates down to the railroad station. During our visit a new steel gallows-frame was being erected at the shaft. At the Ontario some time was spent in studying the immense Cornish pumping plant which was operated about 13 years, raising at times as much as 3,000 gallons of water per minute. The compound driving engine is still intact, but the pumps and rods have been taken out. All of the machinery, however, has been stored in such a way on the surface that it can be studied perhaps to better advantage than if it were in operation. Since the completion of the four-mile Ontario drainage tunnel, the necessity for this great pumping plant no longer exists. It is hardly necessary to say that the extensive underground workings of these two mines proved to be of great interest, though a description cannot be given here.

For the privileges enjoyed by the class at the Park City mines our heartiest thanks are due to the officers of the several companies, but chiefly to the Messrs Bamberger and to Messrs. John A. Kirby, supt., W. F. Sherman, mill foreman, John Nimmo, mine foreman, John Thompson, master mechanic, M. Hennessy, shift boss, W. T. Humes, steward, and Fred. McFadden, clerk of the Daly West, and Messrs. M. J. Daily and Matthew Connelly. superintendents, respectively, of the Silver King and Ontario mines. From all we received a most cordial welcome. At the Daly West we were practically given the freedom of the mine. A comfortable "bunk house," with well-appointed kitchen and dining-room, was placed at the disposal of the class, and all supplies and attendance were furnished at cost.

In addition to the regular class, a number of students made independent trips or obtained positions at various mines, in fulfillment of the summer school requirements, viz.: W. L. Miller, worked eleven weeks in the

Ontario mine; H. B. Jacobsen, three months at the Atlantic Copper mine, Michigan; C. W. Macdougall, three months at the Eustis pyrite mine, Canada; F. Rodriguez, who had already been employed several years at a Mexican mine, studied about six weeks in several of the Leadville and other Colorado mines; J. C. Pickering, worked three and a half months at the Union Copper mine, Gold Hill, North Carolina; A. E. Ring worked and studied three and a half months in several mines in the vicinity of Butte, Montana.

The following named students, having held positions or studied in mines elsewhere, were excused from attendance with the summer class, viz.: Messrs. S. Truax, J. F. Hendrickson, Jr., E. N. Skinner, Sidney Bamberger, W. M. Parkin and F. W. Watson. R. P.

GEOLOGICAL DEPARTMENT.—SUMMER WORK.

The eastern branch of the summer school in geology was held this year at Hudson, N. Y., from June 2d to 9th. It has always been the endeavor of this branch of the school to select a field which combines good stratigraphical, palæontological and structural features. It was conducted last year by Mr. G. Van Ingen at Rondout, N. Y., where these features were excellently combined. This year Becraft Mt., near Hudson, N. Y., was selected. The work was in charge of Professor J. F. Kemp and Professor A. W. Grabau, assisted by Mr. H. W. Shimer. The mountain is about two miles long, a mile wide and four to five hundred feet high. The base is in most places composed of the so-called Hudson River shales, which Rudemann has shown to have resulted from continuous deposition from the beginning of Trenton up to and including the Lorraine. Resting uncomformably upon this and sometimes forming the base of the mountain, but usually showing as a vertical cliff some distance up the sides, is the Manlius (Tentaculite) limestone. It is easily recognized by its finely laminated character. *Leperditia alta* is especially abundant in its upper beds. Resting conformably upon this is the Coeymans' limestone, the lowest stratum of the old Lower Helderberg group. It is distinctly crystalline in structure; this together with the restricted occurrence here of *Gypidula galeatus* makes its recognition easy. The succeeding stratum, the New Scotland, is a calcareous shale characterized normally by *Orthothetis radiata*, *Spirifer macropleura* and *Spirifer perlamellosa;* but interesting transition beds are found between the Coeymans and New Scotland. Upon this rests the Becraft limestone which is composed almost entirely of crinoid joints. Faunally it is especially characterized by *Gypidula pseudogaleatus* and the great abundance of *Spirifer concinna.* The Kingston, the highest member of the old Lower Helderberg group, succeeds this. It is rather shaly and in places contains much chert. *Chætetes* is very abundant in it. Resting upon this is the Oriskany, which here is hard limestone, and contains the characteristic *Spirifer arenosa* and *Spirifer arrectus*, also an abundance of *Diaphorastoma ventricosa.* Upon this rest the Esopus shales which are broken by two sets of cleavages into very narrow and thin, slate-pencil-like pieces; while the Schoharie lying upon this cleaves into broad thin plates. Upon these shales in one portion of the mountain rests the Onondaga limestone. All formations from the Manlius to the Onondaga succeed each other conformably.

These strata form a syncline with a gentle dip of 10°–15° towards the center of the mountain. The structure of the northern portion of the mountain is very simple; the basin begins with the Manlius on each side and the strata follow each other, with few faults to obscure the perfect succession, to the center of the mountain where the Schoharie is found. The southern portion however is much more complex. The original simple syncline has been folded and faulted to such a degree that they remind us of the Appalachian structure.

While most of the week was employed on Becraft mountain one afternoon was also spent in mapping outcrops of Hudson River shales on Mt. Merino. On Saturday upon the invitation of Professor J. C. Smock, late State Geologist of New Jersey, the party enjoyed a drive to Mt. Bob, a few miles north of Becraft. It is only half a mile long by a quarter wide so that a half day was long enough to make cross-sections and map it. The southern portion was found to be a syncline with the Manlius forming the basin and only Coeymans resting in it. The northern portion had the eastern part of the syncline eroded, leaving an eastward-dipping monocline.

The significance of the great unconformity at the base of the Manlius was especially impressed upon the students, by their work in this field. Much attention was also paid to the physiography of the region.

Seventeen students attended the school, making with the instructors a total of twenty. Several students from the more advanced classes in geology undertook a careful study of the faunas of the Helderberg and Oriskany beds, devoting all their time to careful collecting and notation of exact horizons. The rest of the class was divided into squads of two, and each pair made a cross-section of the mountain and mapped a tract areally. Every evening a geological conference was held at which each squad made a report upon their day's work, the conclusions they had reached, their reasons for them, and the difficulties they had encountered. This enabled each one to keep in touch with the work of the others.

As in previous years each squad will prepare a full report with maps, sections, photographs, etc.

The class had as a foundation for their areal work a carefully prepared topographical map, made for Professor Smock and kindly put at the disposal of the school. This map, on the scale of seven inches to the mile and with ten-foot contour intervals, enabled detailed and accurate mapping.

The regular work of the second session in field geology for students in the School of Mines was conducted last year at Marquette, Michigan, by Professor Grabau, owing to the illness of Professor Kemp. This year it was given by Professor Kemp at Bingham Canyon, Utah, during the week beginning July 13th. A geologic map of the region around the principal mines was prepared by a class of fifteen, and observations were also made underground. In connection with this each pair of students will make a petrographical and chemical examination of the different rocks and ores found in the field. Every courtesy was extended to the party by the officials of the United States Mining Company, where headquarters were established, and by others in the camp.

Professor J. F. Kemp left immediately after commencement for Wyoming, and passed a week in the study of the Rambler copper mine and vicinity, under the direction of Dr. David T. Day of the U. S. Geolog-

ical Survey. The occurrence of the platinum group of metals with the copper lends special interest to the mine. Subsequently in company with Professor Wilbur C. Knight, of the University of Wyoming, trips were made to the titaniferous magnetite at Iron Mountain and into the Leucite Hills. Professors Knight and Kemp plan a joint paper upon the latter, many new data having been accumulated regarding the structural geology of the Leucite Hills. At the close of the second session in field geology Professor Kemp returned east to Silver Bay, New York, where he spent the remainder of the summer in preparing MSS. for a folio of the U. S. Geological Survey, the field work for which he had done during previous summers.

Dr. A. A. Julien spent the summer at Cape Cod in the continuation of his study of the Cape Cod sands.

Mr. G. S. Finlay, assistant in geology, spent most of the summer in working up the chemistry and petrography of some rocks from Mexico, the areal work of which he did last winter. He also wrote up the Barre granite of Vermont for the Vermont State survey.

Professor A. W. Grabau and Mr. H. W. Shimer went to Pittsburg directly after commencement to attend the combined meeting of the American Association for the Advancement of Science and the Geological Society of America, and especially the excursions of the latter. This Society convened one week earlier than the American Association so as to enable its members to visit the classic Carboniferous localities under the able leadership of State Geologist I. C. White, of West Virginia. This included many localities in western Pennsylvania and northern West Virginia. Professor Grabau presented two papers before the Society, viz.: "Notes on Gastropods" and "*Spirifer mucronatus* and its Derivatives." The succeeding half month was spent in eastern Pennsylvania, western New Jersey and southern New York in studying especially the Cambro-Silurian limestone and the Lower Helderberg formation.

Then Professor Grabau left for Hudson, New York, near which he worked up Becraft mountain, structurally and stratigraphically, for the New York State Survey. From here he went to Kingston, New York, where he made some exceedingly important discoveries. Then he spent a week at Buffalo and vicinity, making collections from different localities. Another week was spent in southeastern Wisconsin in the study of the Hamilton and the coral reefs of the Niagara formation. From here Professor Grabau went to Petoskey, Michigan, where he made some additional notes on the Hamilton formation of that region. One week was spent in company with State Geologist A. C. Lane, of Michigan, and Mr. B. F. Taylor in a geological exploration of the Beaver Island group. Mr. Taylor located the Algonquin and Nipissing Lake beaches, Professor Grabau worked up the stratigraphical and Dr. Lane the economic geology.

Mr. H. W. Shimer, assistant in palæontology, after separating from Professor Grabau, went to tri-States, New York, near which he spent nearly two months in working up the upper Silurian and lower Devonian rocks structurally and stratigraphically. Immediately after the closing of the eastern branch of the summer school in field geology he worked at the petrography of some dikes for the Vermont State Survey.

Mr. D. W. Johnson, fellow in geology, spent the summer in working up the geology of the Cerrillos Mountains, New Mexico. Special attention

was paid to the intrusives of post-cretaceous age, and their effect upon the turquoise deposit. This was seen well in the mines of the American Turquoise Company. The relation of these intrusives to the anthracite coal was carefully studied, especially in the mines of the Colorado Fuel and Iron Company.

Mr. Fred Moffit, fellow in geology, has passed the last four summers in assisting Professor T. Nelson Dale in the slate belt of New York and Vermont for the United States Geological Survey. He spent most of the past summer in finishing the work in Vermont, and the remainder of the time at Slatington, Pennsylvania. Here he was engaged with Professor Dale in mapping the slate belt for the U. S. Geological Survey.

H. W. SHIMER.

DEPARTMENT OF METALLURGY.

New Officers.—Mr. W. A. Bentley, S.B., resigned the instructorship in metallurgy, July 1, 1902, and has been succeeded by Mr. Bradley Stoughton, Ph.B., Yale, 1893, S.B., Mass. Institute of Technology, 1896.

Mr. Stoughton has had several years' experience in conducting the Bessemer process, and is favorably known as a metallurgist and an administrator.

Mr. Hercules W. Geromanos, S.B., has been appointed tutor in metallurgy.

During the present academic year, Professor H. O. Hofman, Professor of Metallurgy of the Massachusetts Institute of Technology, will deliver the lectures in the course on the metallurgy of copper.

A Full Course in Analytical Metallurgical Laboratory Work.—The most important work of the year has been the development of an analytical metallurgical laboratory course. In the *Columbia University Quarterly* for March, 1901, was given an account of a short metallurgical laboratory course for students in mining engineering. Since that account was written the analytical method of laboratory teaching has been greatly elaborated in the department, so as to provide nearly a hundred experiments for undergraduate and even for advanced students in metallurgy. An idea of what has been done may be got from the following extracts from the preface of Professor Howe's book "Metallurgical Laboratory Notes," * in which these experiments are described in great detail.

"Metallurgical laboratory instruction of the established type reproduces the industrial metallurgical processes, each as a whole, and with such fidelity to actual industrial practice as is attainable. This, which we may call 'Applied Metallurgy,' seems to me to have inherent and very grave faults. In its place I have tried to work out a system of what we may call 'Theoretical' or better 'Analytical Metallurgy,' with the aim of teaching, not individual processes each as a whole, but the individual underlying principles, each by itself. This I have tried to do by means of a series of distinct experiments, each testing one or more of these principles.

"This little book represents the result of my attempt, which, if we leave out of consideration works on the kindred but really distinct sub-

* Published by the Boston Testing Laboratories, 446 Tremont Street, Boston, Mass.

ject of assaying, is, so far as I know, the first serious and systematic attempt in this direction.

"I have endeavored to smooth away every obstacle, with the object not of saving the student trouble, but of enabling him to go farther with a given expenditure of energy, and of permitting me to divert his attention from the laborious details of manipulation to the unwelcome task of thinking.

"A word as to the relative merits of the applied and analytical systems of teaching metallurgy in the laboratory may not be amiss here.

"If the aim of our metallurgical laboratory study is to anticipate industrial practice, we should follow the applied metallurgy plan; if its aim is to teach principles rather than practice we should follow the analytical plan. It seems clear on general grounds that instruction in general should so far as possible deal with principles rather than with the details of practice. But additional reasons, if any are needed, exist in case of metallurgical laboratory instruction. For the details of practice are learnt inevitably, spontaneously, accurately, and with the greatest ease in practice itself, but with very great difficulty and distortion in the laboratory. Principles, on the other hand, are what the laboratory teaches most readily and perfectly, and practice least readily and most imperfectly. The path of least resistance then is to study principles in the laboratory and the details of practice in practice itself.

"* * * the metallurgist has to practice both as a manufacturer, and as an investigator of the conditions of his manufacture and of the qualities of his product. The two functions are in a great measure distinct, like walking and swimming. In the manufacture proper great accuracy is rarely appropriate; in investigating the processes and products of the manufacture the greatest accuracy may be needed. Now, just as the water is the place to teach swimming and the land to teach walking, so the industrial establishment is the place to teach the degree of accuracy appropriate for manufacture, and the laboratory to teach the greater accuracy which these investigations will need; more especially because this kind of accuracy the industrial establishment does not teach.

"While I hold these views, yet as the art itself of teaching must be chiefly empirical, and as changes should therefore be made tentatively and their merit tested, I have elaborated also experiments for teaching certain industrial processes in the older or applied metallurgy method, so that the working of the two methods may be compared.

"Another and important work of the metallurgical laboratory is to give a certain skill in the use of the instruments of precision of the art, in pyrometry, calorimetry and the microscopy of metals and alloys. It seems to me nearly as imperative that the metallurgist's diploma to-day should imply this skill as that the civil engineer's should imply skill in the use of the transit."

"With a very few exceptions all the experiments in this work have been carried out either in the metallurgical laboratory of the School of Mines of Columbia University, or earlier in the author's private laboratory, and either exactly in the form here given, or in a form of which the present is a slight modification, and it is hoped an improvement."

"While most of these experiments are brief, yet there are some of which each is sufficiently extended to serve as an investigation for a graduation thesis, and others of intermediate length.

"This work would have been impossible but for the zealous coöperation of the officers and students of the School of Mines of Columbia University, on whom the labor of the actual manipulations has fallen. My heartiest thanks are due to them, and especially to Messrs. Bradley Stoughton and E. J. Hall, whose devotion to the work has known no bounds."

"The gas furnaces used, in addition to the well known Fletcher and Forquignon furnaces, are those of the American Gas Furnace Company. To its President. Mr. F. J. Reichelm, thanks are due for the great pains which he has taken in designing special furnaces for this work."

"The experiments of Group 1 are designed especially to enable a few instructors to give to a large class of students a slight smattering of metallurgical conditions. To this end it is arranged that the students work in squads each under a captain chosen from among them by the instructors; and the directions are given in very great detail."

The Summer School, this year, studied the metallurgy of lead, copper, gold and silver, in the vicinity of Salt Lake City, Utah, and the metallurgy of iron and steel at Phœnixville, Pa. At the latter place an investigation was made by the students, under the direction of Mr. Stoughton, into the thermal efficiency of an open-hearth steel furnace.

The Summer School at Utah was in charge of Mr. Stoughton, assisted by Prof. R. H. Bradford, of the University of Utah.

Investigations and Publications.—Three men of uncommon powers have been studying in the department during the past year, Prof. R. H. Bradford, of the University of Utah; Dr. John A. Mathews, Barnard Fellow and Carnegie research scholar of the British Iron and Steel Institute, and William Campbell, University Fellow.

The following publications have been made by officers and students in the department:

Professor Howe:

"L'Enseignement du Laboratoire de Metallurgie"—extract from *La Revue Internationale de l'Enseignement*, 1901.

"What is the Essence of Crystalhood?" *The Metallographist*, V., January, 1902, 3.

"The Freezing-Point Curve of Binary Alloys of Limited Reciprocal Solubility when Molten." *The Metallographist*, V., April, 1902, 166.

"Metallurgical Laboratories." *Science*, N. S., May 16, 1902, XV., No. 385, pp. 761–766 (an address delivered at the opening of the Gayley Laboratory of Chemistry and Metallurgy, at Lafayette College, Easton, Penn.).

"Metallurgical Laboratory Notes." Boston Testing Laboratories, Boston, Mass., 1902 (pp. xiv, 140), illustrated, price $2.50.

Mr. Stoughton:

"The Development of the Bessemer Process for Small Charges." *Trans. Am. Inst. Mining Engineers*, Philadelphia meeting, May, 1902.

Professor Bradford:

"The Reactions of the Ziervogel Process and their Temperature Limits." *Trans. Am. Inst. Mining Engineers*, Philadelphia meeting, May, 1902.

William Campbell:

"Crystallization Produced in Solid Metal by Pressure." *The Metallographist*, January, 1902, V., 57.

"The Microscopical Examination of the Alloys of Copper and Tin."

Institution of Mechanical Engineers (read Dec. 20, 1901), Appendix to 6th Report of Alloys Research Committee. *Engineering*, Jan. 4, 11 and 18, 1902, LXXIII., abstracted in *Nature*, LXV., 354.

"The Microscopical Examination of the Alloys of Copper and Tin." Rewritten in part and entirely reillustrated. *The Brass Founder and Finisher*, I., 73.

"The Alloys of Aluminium" (with J. A. Mathews). *Jour. Am. Chem. Soc.*, XXIV., 253.

"Upon the Structure of Metals and Binary Alloys." *Jour. Franklin Inst.*, July–September, 1902.

John A. Mathews:

"The Alloys of Aluminium" (with William Campbell). *Jour. Am. Chem. Soc.*, XXIV., 253.

"Alloys as Solutions." *Eng. and Mining Journal*, Dec. 21 and 28, 1901, LXXII.

"A Comparative Study of Some Low Carbon Steel Alloys." *Jour. Iron and Steel Inst.*, 1902, I., 182.

"Upon the Constitution of Binary Alloys." *Jour. Franklin Inst.*, January–March, 1902.

Honors, etc.—Professor Howe has been elected Honorary Member of the Russian Imperial Technical Institute of St. Petersburg.

At the Budapest Congress of the International Association for Testing Materials, in September, 1901, he was elected President of the most important section, that of metals, as well as Honorary President of the whole Congress.

He delivered an address at the opening of the Gayley Laboratory of Chemistry and Metallurgy at Lafayette College, Easton, Penn., April 5, 1902.

Professor Bradford's investigation has brought him the degree of Ph.D. at Columbia; Dr. Matthews' has brought him the Carnegie gold medal of the British Iron and Steel Institute; Mr. Campbell's has brought him the Carnegie Research Scholarship of the British Iron and Steel Institute for the coming year.

Professor Bradford's very important work was made possible by the appliances for very precise heating which have been developed for the use of the department.

New Apparatus.—The department has added during the year a chlorination barrel; six amalgamating pans; electrolytic arrangements for the electrolysis of copper; a set of rolls driven with power, for investigating some of the more pressing industrial questions connected with the properties of steel; three electric and two gas furnaces with special appliances for extreme accuracy of temperature control; a small reverberatory furnace; and a large number of Le Chatelier thermo-electric pyrometers, one of which is fitted with a new autographic attachment, developed in this laboratory by William Campbell, Esq. Hereafter each student in the course of metallurgical engineering will have the exclusive use of a Le Chatelier pyrometer throughout his course. This step has been found desirable, because almost every investigation or experiment tried is the better for having its temperature under direct control. The cupola furnace and the English cupelling furnace presented by Messrs. Fraser and Chalmers have been placed in position and are now ready for use for the smelting of copper ores, etc. H. M. H.

BOOK REVIEWS.

The Mineral Industry; Its Statistics, Technology and Trade in the United States and other Countries, to the end of 1901. Vol. X. The Engineering and Mining Journal (Inc.), New York and London, 1902. $5.00.

This well-known annual publication, begun ten years ago by the late Richard P. Rothwell, and since his death edited by Dr. Joseph Struthers, has made a permanent place for itself as a book of reference among all who are in any way interested in mining and metallurgy. In value and completeness, the present volume is fully equal to the best of its predecessors.

The work begins with a concise statement—in part tabulated—of the production of ores, minerals and metals, in the United States only, the figures being given in parallel columns for the years 1900 and 1901. In this statistical statement of quantities and values a clear distinction is made between "First Products," "Secondary Mineral and Chemical Products" and "Metals Produced in the United States from Foreign Ores and Bullion," so that the reader is not confused by having to separate the various items himself, and the totals are presented in their true proportions. Following this introductory chapter, the minerals and metals are taken up in alphabetical order, the information given under each head comprising details relating to the world's production, modes of occurrence, places of production and uses in art and manufactures, together with further details as to quantities and values. Generally, throughout these resumés, comparative tabulated figures are given for the five years, 1897–1901 inclusive, or 1896–1900 inclusive, thus presenting at a glance the commercial trend of each branch of the industry. In each chapter, furthermore, accounts are given of improvements or changes in modes and processes of production. Many of these technological accounts are of the nature of monographs, written by specialists, whose reputation in their several lines furnishes a sufficient guarantee as to accuracy of statement. Among the most elaborate of these papers are: "The Manufacture of Coke in the United States, with Special Reference to the Markets for By-Products," by F. Schniewind, 30 pp., illustrated; "Progress in Electro-Chemistry and Electro-Metallurgy in 1901," by John B. C. Kershaw, 22 pp.; "A Review of Progress in the Cyanide Process in 1901," by J. S. C. Wells, 27 pp.; "Recent Improvements in Lead Smelting," by H. O. Hofman, 20 pp.; "Production of Natural Gas in the United States," by W. H. Hammon, 18 pp.; "Progress in the Sulphuric Acid Industry during 1901," by F. J. Falding, 36 pp., illustrated; and "Progress in the Metallurgy of Zinc in 1901," by W. R. Ingalls, 26 pp, illustrated.

A resumé of the business done during the past year in the leading stock exchanges of the United States and Europe is given on pages 485 to 804.

The book concludes with a tabulated statement, occupying 80 pages, of the quantities and values of the more important mineral products of

the different countries of the world. This information is given in a condensed form, rendering it most convenient for reference, and evidently representing a vast amount of labor.

It will be noted that, in a number of cases throughout the work, in treating of substances produced largely in foreign countries, the figures of production are not brought up later than to the end of 1900. The reason for this will be readily appreciated by anyone who has had occasion to investigate such statistics. Accuracy is of the first importance, and great difficulty is often experienced in obtaining promptly reliable data from some of the foreign mining districts. Moreover, where the figures given are not based upon exact and authentic information, the items are marked "estimated" in footnotes.

An index of 35 pages is not the least valuable feature of this useful book, the preparation of which reflects great credit on the editor.

R. P.

The Electro-plating and Electro-refining of Metals, being a new edition of Alexander Watt's "Electro-Deposition." Revised and largely rewritten by ARNOLD PHILIP, Asso. R.S.M., B.SC., A.I.E.E., F.I.C. D. Van Nostrand Company, New York; Crosby Lockwood & Son, London, 1902. Pp. 678. Price, $4.50, net.

The present book on Electro-plating and Refining of Metals is an extension of the well-known work of Alexander Watt on electro-plating. The book is divided into two parts: Part I. on Electro-plating and Part II. on Electro-metallurgy. The subject of Electro-plating is one in which comparatively little trustworthy information can be obtained, perhaps because it is one of the branches of electro-chemistry which has had so little development within recent years, therefore any work which aims at bringing this subject more up to date is to be commended.

The subject matter in Part I. begins with a description of sources of electric energy, both primary and secondary batteries being considered, and then takes up thermopiles in some detail, following with information on dynamos and dynamo tending; the main subject of plating is then entered upon and the metals considered in detail and this portion seems to be much the same as in the Watt edition of 1889, and is perhaps the best thing we have on the subject.

Some newer processes are taken up in Apendix II. of this part, such as the Cowles process for electro-plating, parabolic mirrors for searchlights, etc. Part II. on electro-metallurgy enters on a description of copper refining by electricity, four chapters being devoted to this most important branch of electro-chemistry. Then follows some of the newer industries such as the electrolytic refining of gold and silver bullion, the recovery of tin from scrap, the electrolytic refining of lead, electro-galvanizing and the extraction of aluminum.

These processes are all described in some detail and in many cases the question of cost is entered into. A number of useful tables are to be found at the end of the book, togetner with a name and subject index.

S. A. TUCKER.

Woodbridge School,

FORMERLY

School of Mines Preparatory School.

---

417 Madison Avenue,

Between 48th and 49th Streets, NEW YORK CITY

Twenty-second Year Begins October 1st, 1903.

THE school is well equipped with physical and chemical laboratories, in which the students are required to perform a complete set of experiments illustrative of their recitations in physics and general chemistry. A special laboratory is devoted to qualitative chemical analysis for advanced students.

Five hundred Students of Columbia School of Mines have been instructed in the Woodbridge School. Also a large number have been prepared for Massachusetts Institute of Technology, Stevens Institute, Sheffield Scientific School, Lawrence Scientific School, Troy Polytechnic Institute, Cornell University, and the Classical, Medical, and Law Departments of Harvard, Yale, Columbia and Princeton.

A summer school for students who have failed in June begins August 13th and coaches men for the Fall examinations. All classes are limited to five. College men are coached in Freshman and Sophomore Mathematics and Quantitative Analysis.

An advanced course for older students prepares them to enter the second year class Last June one of our students received his degree in Electrical Engineering in three years.

VOL. XXIV. No. 2. JANUARY, 1903.

THE SCHOOL OF MINES QUARTERLY.

A

JOURNAL OF APPLIED SCIENCE.

BOARD OF EDITORS.

A. J. MOSES, Prof. of Mineralogy.
J. F. KEMP, Prof. of Geology.
R. PEELE, Adj. Prof. of Mining.
A. D. F. HAMLIN, Adj. Prof. of Architecture.
R. E. MAYER, Instructor in Drawing.
E. WALLER, Analytical Chemist.
JOS. STRUTHERS, Ph.D., Lecturer in Metallurgy.
I. H. WOOLSON, Instructor in Mechanical Engineering.
W. H. FREEDMAN, E.E.,
T. H. HARRINGTON, Tutor in Drawing.

Managing Editor, R. E. MAYER.
Business Manager, T. H. HARRINGTON.

CONTENTS:

On the Use of Influence Lines in Graphic Statics. By Myron S. Falk, 119
The Morphology of Certain Organic Compounds. By Austin F. Rogers, 130
A Study of the Quantitative Determination of Antimony. By Lewis A. Youtz 135
Upon the Structure of the Starch Molecule. By F. E. Hale 145
Ogden N. Rood 171
The Geology of the Cerrillos Hills, New Mexico. By Douglas Wilson Johnson 173
Abstracts—Notes on Recent Mineralogical Literature. By Alfred J. Moses and Lea McI. Luquer 248
Book Reviews 268

COLUMBIA UNIVERSITY
NEW YORK CITY.

Registered at the New York Post Office as Second Class Matter.

TWO DOLLARS PER YEAR. FIFTY CENTS PER NUMBER.
All Remittances should be made payable to Order of "The School of Mines Quarterly."

Portland Cement

THE LAWRENCE CEMENT CO.

ESTABLISHED 1832.

ERNEST R. ACKERMAN, President

This Company has manufactured and sold during 70 years upwards of **20,000,000** barrels of Cement; marketing the product in all the principal cities of the United States, Canada, West Indies, Philippines and South America.

The old Custom House on Wall Street, built in 1835–37, and the new Custom House on Bowling Green, now under construction, were built with cement sold by this Company.

Used on the Old and on the New Stock Exchange in New York City, on the Brooklyn Bridge and New East River Bridge, and on the new Chamber of Commerce Building.

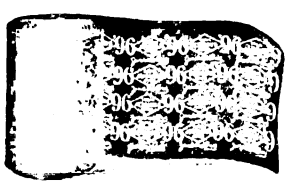
Detailed list of important Government Work, Reservoir Dams, Sidewalks, Fortifications, Bridges, Municipal Buildings and Railroad Work where "DRAGON" has been used, furnished on application.

DRAGON PORTLAND CEMENT Stands the Highest Requirements of Architects, Engineers and Builders.

SALES OFFICES:

NEW YORK, No. 1 Broadway. 15th and Market Sts., PHILA.

JENKINS '96 SHEET PACKING



The Perfection of Joint Packing.

Makes joint instantly; does not have to be followed up. Makes joint that will last for years on all pressures of steam, oils, acids, &c. Does not rot, burn, blow or squeeze out.

Received the Highest Award GOLD MEDAL At the Pan-American Exposition.

All genuine stamped with Trade Mark.

Jenkins Brothers, New York, Boston, Philadelphia, Chicago, London.

THE

SCHOOL OF MINES QUARTERLY.

VOL. XXIV. JANUARY, 1903. NO. 2.

ON THE USE OF INFLUENCE LINES IN GRAPHIC STATICS.

BY MYRON S. FALK.

An influence line is a line showing the variation in any function at any section of a beam or in any member of a truss caused by any load moving across such beam or truss. It is clear that such a line can be used to indicate the position of the moving load causing the *maximum* shears, moments, reactions, or stresses in a truss, and it is for the purpose of indicating and obtaining such maxima that influence lines are used.

ART. 1. INFLUENCE LINE FOR REACTION.

A reaction influence line is a line showing the variation of the reaction of a beam under a crossing load. If AB (Fig. 1) represents a simple non-continuous beam, of length l, and P_1 a load moving over the beam from right to left, its distance at any instant from the right abutment being represented by x, the reaction R at the left will be given by the following equation, which is the equation of a straight line,

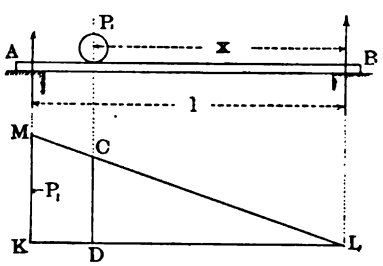


FIG. 1.

$$R = \frac{P_1 x}{l}.$$

If a line, KL, parallel to the beam and of equal length, be laid off below the beam and an ordinate be erected at the left-hand end representing to scale the load P_1, a line, ML, connecting the end of this ordinate with the opposite end of the base line will be a line expressing Eq. 1 graphically. If the load be at the distance x from B and an ordinate CD be erected immediately below this point, the triangles CDL and MKL will be similar, and, therefore,

$$\frac{CD}{DL} = \frac{MK}{KL} \text{ or } CD = \frac{P_1 x}{l}.$$

This equation shows that an ordinate between the line ML and KL will represent the reaction at the left-hand end of the beam for the load P_1 placed at a point immediately over the ordinate; therefore, the line ML is an influence line for reaction, since it shows the variation of the reaction as the load P_1 crosses the beam.

The influence line thus constructed for a load P_1, may be used for any other load Q, it being necessary, however, to multiply the value of any ordinate drawn for P_1 by the ratio of Q/P_1. This applies to any influence line which may hereafter be constructed.

ART. 2. INFLUENCE LINE FOR SHEAR.

An influence line representing the variation of shear at any section, CD, in a beam (Fig. 2) as a load crosses the beam is derived in a similar manner. As a load P_1 advances towards the section, the shear at any instant will be equal to the reaction R, or $P_1 x/l$, and, as before. may be represented graphically by the line LM.

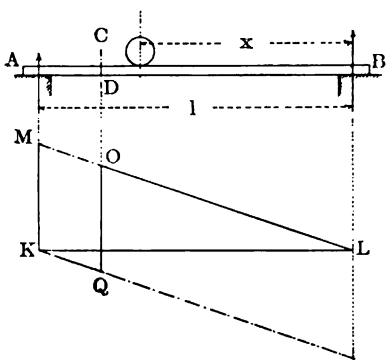


FIG. 2.

After passing the section, however, the shear becomes equal to the reaction R minus P_1, and is, therefore, a negative quantity. To represent this graphically, ordinates of a value P_1 must be drawn downwards from the line OM, and the locus of the ends of these ordinates will be the line KQ parallel to the line LOM. The line $LOQK$ will then represent the variation of the shear at the section CD

as the load P_1 crosses the beam, the shear being positive and of an increasing positive value as the load advances towards the section, and negative and of a decreasing negative value as the load leaves the section. It is seen that the maximum positive shear is found when the load is just to the right of the section in question. In practice, the load is always placed at the section.

If two equal loads, P_1, separated by a fixed distance a, be employed, the maximum shear will be found when the first load is just at the section, and the value of the shear will be the sum of the ordinates erected below the two wheel loads.

If two unequal loads, P_2 and P_3, separated by a fixed distance a, be employed, maximum values of the shear will be found when either load is just at the section. If the influence line be drawn for a load P_1, then, for the load P_2 placed at the section, both loads P_2 and P_3 being on the beam, the shear will be represented by the algebraic sum of the product of the ordinate corresponding to P by the ratio of P_2 to P_1, and of the product of the ordinate corresponding to P_3 by the ratio of P_3 to P_1.

If the loading advances to the left to such a position that the load P_3 is just at the section, the shear will be represented by the algebraic sum of corresponding products. Trial alone determines which position causes the greater maximum shear at the section; the second position of the loading will usually give the greater maximum shear, if P_2 be small compared with P_3, if the distance a be large, or if the section CD be near the left abutment.

This construction can be used in the finding of the maximum shear at any section of a beam when a series of concentrated loads separated by fixed distances, as in the case of a locomotive, is used. The operation in such a case is as follows:

A unit influence line having been drawn, the algebraic sums of the products of ordinates erected under the various wheel loads by the actual weight of each load, must be compared for positions of the loading when different wheel loads are just at the section in question; the values of the quantities so found will indicate not only the position of the loading for maximum shear, but will give the value of the shear. This operation is not as tedious as it may at first appear, since it is evident that the greatest maximum shear usually occurs with the head of the locomotive near the section. Attention is called to the fact that should the

loading advance so much to the left that new loads appear upon the span at the right, such new loads must not be neglected.

Art. 3. Influence Line for the Reactions of a Series of Concentrated Loads.

The influence lines so far considered have involved in their construction the use of only one load; and the use of such lines, in the case of more than one load, has required the use of arithmetical calculations. There will now be considered the construction of a line such that the variation of the reaction of a beam, as well as the reaction itself, when a series of concentrated wheel loads passes over the beam, may be measured directly from the drawing.

In order to simplify the explanation, only three loads, P_1, P_2 and P_3, separated by the fixed distances a and b, will be used, but the

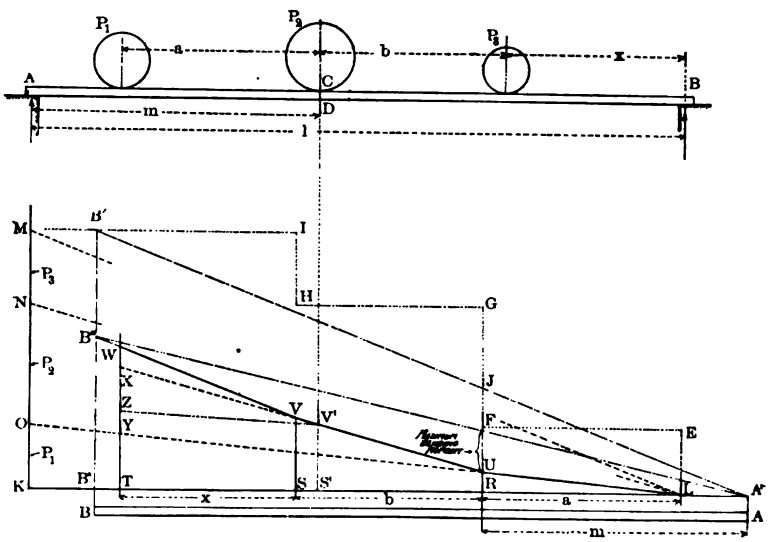


Fig. 3.

construction can be applied with ease to any number of loads. Let the positions of the loads be shown in Fig. 3, x representing the distance of P_3 from the right abutment. Taking moments about the right abutment, there will be obtained:

$$R = \frac{1}{l}[P_1(a + b + x) + P_2(b + x) + P_3 x]. \qquad (1)$$

As before, let KL represent the base line equal in length to the span, and let KM represent to scale the loads P_1, P_2, P_3, laid off upwards from K and in consecutive order. From L lay off to the left, in consecutive order and to proper scale, the distances a, b and x. Draw the lines ML, NL and OL. At R erect an ordinate RU to the line LO. From U draw a line UV parallel to NL to the intersection with an ordinate erected from S. From V draw a line VW parallel to LM to the intersection with an ordinate erected from T. *Then WT will represent the reaction at the left end of the beam for the positions of the loads as shown.* For WT is composed of the three parts, TY, YX and XW, found by continuing LU and UV to intersect WT. By construction, the triangles OKL and YTL are similar. Therefore,

$$\frac{YT}{TL} = \frac{OK}{KL}.$$

Substituting the values of those quantities which are known, it is found that

$$YT = \frac{P_1(a+b+x)}{l}.$$

The triangles NOL and XYU are also similar by construction; therefore,

$$\frac{XY}{TR} = \frac{NO}{KL}.$$

Again, substituting the values of those quantities which are known,

$$XY = \frac{P_2(b+x)}{l}.$$

By construction, the triangles MNL and WXV are also similar. Therefore,

$$\frac{WX}{TS} = \frac{MN}{KL} \text{ or } WX = \frac{P_3 \cdot x}{l}.$$

By summation,

$$YT + XY + WX = \frac{1}{l}\left[P_1(a+b+x) + P_2(b+x) + P_3x\right],$$

or the reaction at the left-hand end of the span, as already shown by Eq. (1).

The loads may move any distance x upon the bridge. This involves no change in the figure as drawn. To find the reaction for such a change in the position of the loading, an ordinate must be erected at a distance from the left end of b equal to the new distance x; *the intercept on this new ordinate between KL and the line VW continued will give the new reaction.* The line $LUVW$ is thus an influence line for reactions, since it shows the variation in the reaction as the loads P_1, P_2 and P_3 move across the bridge. Thus the ordinate immediately below P_1 represents the reaction for that position of the loading.

In using a uniform load in this form of construction, the uniform load should be treated as a series of concentrated loads spaced as closely together as the accuracy of the problem may demand.

Art. 4. Influence Line for Maximum Shear, for a Series of Concentrated Loads.

It can now be shown that the line constructed in the manner described in the preceding article, can also be used as an influence line to find the maximum shear at any section of a beam. Let CD, Fig. 3, be the section of the beam under consideration. If P or the first wheel load, is just at this section, the shear is equal to the reaction due to the loads on the beam or to $S'V'$. If the loading advances till P_2 is just at the section, the shear at the section becomes equal to the reaction, shown by the ordinate $W1 - P_1$. P_1 can therefore be laid off downwards from W as WZ. The shear is then represented by TZ. If the line $V'Z$ slopes downward to the left, it is evident that the shear with wheel load P_1 at the section is the greater; if the line slopes upward to the left, it is evident that the shear is greater with the wheel load P_2 at the section. Should P give a greater shear, it is a simple matter to test for wheel load P_3 at the section, or in actual practice, any number of wheel concentrations, as in the case of a locomotive. The line $LUV'Z \cdots$ is evidently an influence line for shear at the section CD.

Art. 5. Maximum Moments in a Beam.

It may be advisable to explain, at this time, that the influence line for reactions, as described in the preceding article, is also a funicular polygon for which the pole distance is the perpendicular distance between the pole L and the line MK. This polygon differs

from the ordinary funicular polygon, however, in that the various loads and distances are laid off in order exactly reverse to the usual procedure; that is, the loads are laid off upwards beginning with P_1, and the distances a, b, etc., are laid off from right to left beginning at the right with a; this brings the head of the moving load to the right, whereas in preceding uses of the figure the head of the moving load has always been at the left. The meaning of this construction should be carefully noted.

In finding the maximum moments in a beam, it will be assumed that the reader is familiar with the use of a funicular polygon as a moment polygon in the case of parallel forces and also with the use of the criterion employed in finding the position of a moving load to give the greatest bending at any section of a beam. If l represents the length of the beam, l' the distance of the section under consideration from the left abutment, W all the loads on the bridge and, W' the loads to the left of the section, then, for maximum bending in the section:

$$\frac{l'}{l} = \frac{W'}{W}.$$

In order that the condition of equilibrium expressed by this equation may hold, it will usually be found necessary to place a load directly at the section, since then any portion of this load may be considered to be on either side of the section. This criterion may be used in a very simple manner in graphic construction.

In Fig. 3 draw LE equal to P_1 vertically above L; from E draw a horizontal line until it meets at F an ordinate drawn vertically from R. Lay off FG from F equal to P_2; from G draw a horizontal line GH, etc.; follow this same form of construction for the remainder of the loads. The result will give the stepped diagram $LEFGH\cdots$ representing graphically the summation of all the loads, and also of all the distances from the head of the moving load to any other point in the moving load.

In the case in hand it is desired to find the position of the moving load to cause the maximum bending moment at the section CD distant m from the left abutment. Take a strip of paper and lay off on its edge to scale the length of the beam l and from the *right-hand* edge of l lay off m. It is important to notice that although the section is distant m from the left abutment, the distance m must be measured from the right-hand side on

the funicular diagram, since this polygon is in a position reverse to the usual. Move the strip of paper until the load P_2 or FG is over the section under consideration. If this position then gives a maximum bending moment, the condition of the criterion should be fulfilled. Erect vertical ordinates at the ends of the beam and at the section until these ordinates intersect the stepped diagram at A', B' and J. Draw a line from A' to B'; if the line $A'B'$ passes through the step of the diagram representing the load situated at the section the criterion will be fulfilled and this position of the loading will cause maximum bending. For in the similar triangles RJA' and $B''B'A'$,

$$\frac{RJ}{B''B'} = \frac{RA'}{A'B''}; \text{ that is } \frac{W'}{W} = \frac{l'}{l}.$$

Should the line $A'B'$ not pass through the step GF the strip of paper must be moved until another load is brought to the section and the construction above described must be repeated.

If, as in the present case, the conditions of the criterion are fulfilled, the bending moment can be immediately obtained. Erect vertical ordinates upon the ends of the beam until they intersect the influence line at B''' and A'. Connect these points of intersection. As in the usual construction the value of the vertical intercept between this line $B'''A'$ and the influence line, when multiplied by the pole distance, will give the bending moment at any section. In this way this one diagram can be made to serve in finding both maximum shears and maximum bending moments in a beam.

In actual practice it may be found advisable in constructing the influence line to take as a pole distance not the entire length of the beam, but only some fractional part of it. This will cause the influence line to have a steeper inclination and will tend to make more accurate the measurement of all vertical heights; evidently these will all be increased in the same ratio. Care must be taken in such a case to give to all ordinates whether for shear or bending moment, their proper values.

Art. 6. Maximum Stresses in the Web Members of a Truss with Parallel Chords.

It will be assumed that the following principle is familiar to the reader: the stress in any web member of a truss having parallel chords is equal to the shear in the panel multiplied by the secant

of the angle which the member makes with a vertical. If the shear is known, the stress can be found very simply by a graphical construction. Let the vertical side of a right-angled triangle represent to scale the shear, and let the hypothenuse make an angle with this line equal to the inclination of the web member with a vertical. Then the hypothenuse will represent to scale the stress in the member.

Therefore, in order to find the maximum stress in a web member, it will be necessary to find the maximum shear in the panel in which the member is situated, and this shear will be found graphically by means of an influence line differing but slightly from the influence line for maximum shears in a beam. The change involved arises from the fact that the loading in the present case is applied at the panel-points of the chord; it is seen that this application of the load affects only the panel under consideration, for, in the other panels, the loads, whether considered as they stand or as if concentrated at the panel-points, cannot influence the shear in the panel under consideration.

The shear in any panel is constant between panel-points, and is equal to the reaction at the left-hand end of the truss minus all the loads which may be situated in the panels to the left of the panel under consideration, and minus that portion of the loading situated in the panel itself, and which is transferred to its left-hand end. It is evident then that for maximum shear, no load should pass the panel itself. There only remains to be considered the distance which the locomotive must advance on the panel in question.

As an illustration, the maximum stresses in some of the web members of an 8-panel, 208-ft. Pratt truss will be determined, using as the loading the locomotive concentrations designated in Cooper's specifications as E 40.

Let AB, Fig. 4, represent the truss under consideration. Draw the base line KL equal in length to the total length of the truss; beginning at L, and with wheel 1, lay off on KL and towards the left to scale, the distances between the various wheel loads, and erect vertical ordinates at the points thus found. It should be noted that the uniform load is treated as a series of concentrated loads, each concentration representing ten feet of uniform load. At K erect the vertical KM, and lay off on KM upwards to scale the amounts of the loads, beginning at K, with wheel 1. Connect the points thus found with L, which becomes the pole of the funicular polygon, and by the aid of these lines draw the funicular polygon

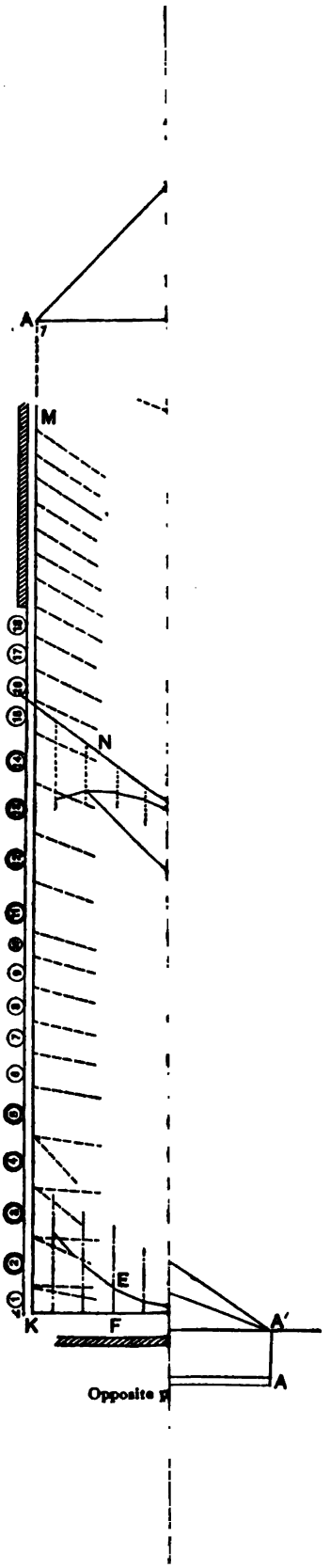
$LD'' \cdots N$. As already demonstrated, this is an influence line for reactions and for shears for a beam with the span KL.

In order to use this line in the present case, it will be necessary to find the reactions at the left-hand end of any panel when loads are found within such panel. For this purpose, a similar influence line must be drawn, using in this case, however, the panel length as the length of span. This second influence line is shown in the left-hand corner of the figure as RE; in this case R is the pole.

In order to find the maximum stress in any member, such as b-4, for example, it will be necessary to find the maximum shear in the panel 3-4; the two influence lines already constructed are then to be combined for this purpose. From panel point 4 let fall a vertical ordinate upon the line $LD'' \cdots N$; the point of intersection falls at G, and GH represents the shear at the panel point 4, and also in the panel when wheel load 1 is at this point. If the load advances so that wheel load 2 is at this panel point, the shear cannot be measured directly from the original influence line $LD'' \cdots N$ with its value diminished by wheel load 1; the shear is now diminished only by that portion of the wheel load 1 which is carried to panel point 3. The value of this portion is known from the line RE, and its position relative to the panel point 4 is also known. Therefore, this value is drawn at the proper point as a negative ordinate from the line $LD'' \cdots N$.

This same construction is followed for other positions of the loading, such that other drivers come at panel point 4. The final resulting line is GSU, and ordinates between the base line KL, and GSU will then show the shear in the panel, as the loading advances toward the left. By inspection it is then seen that the maximum shear is TS; by employing the construction noted in the beginning of this article, the line SU will represent to scale the stress in b-4. The stress in the vertical b-3 is found at the same time and is equal to the maximum shear in the panel or TS.

A similar method of procedure is followed in the case of all the other web members, including as such also the end post. The operation is performed very expeditiously since the same load is treated at one time in all the panels. By this means the counter stresses in the members are found at once, for the stresses in those members situated to the right of the center of the truss, indicate the maximum compression which can exist in the corresponding members to the left of the center; simply for convenience, the


A
M
N
E
K
F
A'
A
Opposite p

stresses for these members have been drawn as sloping to the right instead of to the left.

The dead load stresses can be found as in the usual manner by a force polygon, or by representing the shears in the truss by a stepped diagram, and again making use of the construction noted above.

Art. 7. Maximum Stresses in the Chord Members of Truss with Parallel Chords.

In order to find the maximum stresses in the chord members of a truss with parallel chords, the principle of sections will be employed, with the use of which it is assumed that the reader is familiar. The method used, however, can only be applied, as far as the present analysis has been carried, to those trusses, in which the center of moments is found in a vertical line drawn through a panel point of the loaded chord. The truss and loading used in the previous article will again be employed and the maximum stress in the upper chord member b-c will be determined. Panel point 4 is the center of moments for this case; therefore, the maximum moment at the point 4 must be found. As already noted, the funicular polygon $LD'' \cdots N$ is in a reverse position with regard to the loading as the concentrations advance on the truss. Let the line BA below the line KL represent the truss, laid off to scale on a strip of paper, and the point 4 represent the center of moments. By use of the stepped diagram, explained in Art. 5, it is found that wheel 9 at the section gives one position for maximum bending. By erecting ordinates AA' and BB'', and drawing the line $A'B''$, the bending moment $C''D''$ is graphically obtained, and must be multiplied by the pole distance in order to be expressed in proper units. The maximum live load stress in b-c is the bending moment thus found divided by the depth of truss. The dead load stress is found either by a force polygon or by means of a moment curve.

In this way use has been made of one construction to serve in finding in a simple and elegant manner, and in a manner such that errors can be immediately detected, the stresses due to any moving load in any truss having parallel chords and web members of the kind above indicated. The modifications necessary to apply this treatment to more general cases, such as trusses with broken chords, or trusses with all web members inclined, or even unsymmetrical trusses will be developed in a subsequent article.

THE MORPHOLOGY OF CERTAIN ORGANIC COMPOUNDS.*

By AUSTIN F. ROGERS.

A crystallographic study of certain organic compounds furnishes the following notes. The potassium cyanate and mercuric oxycyanid were obtained from the chemical firm of Eimer & Amend. The other compounds are from the Laboratory of Organic Chemistry of Columbia University, and were kindly placed at the disposal of the writer by Prof. M. T. Bogert, of that department.

Potassium Cyanate, KCNO.

Monoclinic:

$$a:b:c = 2.6177:1:1.2819:\beta = 86° 11'.$$

Observed forms:

$$a\{100\}\ c\{001\}\ m\{110\}\ r\{101\}\ \{\bar{h}01\}\ z\{112\}.$$

			Measured.		Calculated.	
cm	(001 : $1\bar{1}0$)	(12)	*94°	51′		
mm′	(110 : $\bar{1}10$)	(12)	*41	54		
cr	(001 : 101)	(6)	*23	4		
ar	(100 : $10\bar{1}$)	(4)	*53	7		
cr′	(001 : $\bar{1}0\bar{1}$)	(3)	126	51	126°	53′
mr	(110 : 101)	(3)	77	31	77	54
mr′	(110 : $\bar{1}0\bar{1}$)	(4)	102	22	102	6
cc	(001 : *oo1*)	(8)	9	44	9	42
$\bar{m}\underline{m}$	(110 : *ıı0*)	(2)	96	9	96	12

Cleavage *r*, good; *m*, good; *a*, imperfect. Twins. Twinning plane *m*. Simple twins and cyclic groups.

Simple crystals exhibit the forms *m*, *c* and *r*. They are tabular in habit, being flattened parallel to one of the *m* faces, and this unequal development of the *m* faces gives them the appearance of triclinic crystals.

A second crop of crystals consisted almost entirely of twins of varying degree of complexity. Some are simple twins composed of two individuals (Fig. 1). Cyclic groups are more common and

* From Ph.D. Thesis.

they made up of from 3 to 11 individuals on which the forms *a*, *c*, *m*, *r*, *z*, and an indetermined *hol* are present (see Figs. 2–5). The cyclic arrangement is brought about by continued twinning parallel to two faces of the unit prism.

Twinned individuals on the exterior are always reduced to narrow bands and frequently such are introduced in the interior. This arrangement is due to successive twinning about the same face and

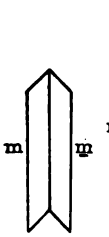


FIG. 1.

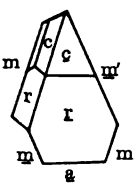


FIG. 2.

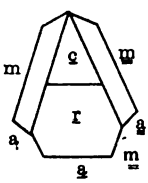


FIG. 3.

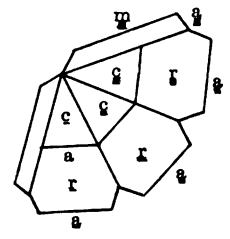


FIG. 4.

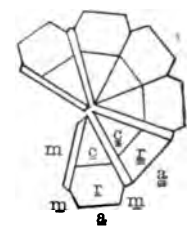
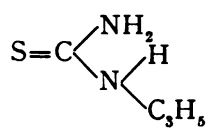


FIG. 5.

gives an appearance of twinning after two different laws. The cyclic twins simulate monoclinic domatic symmetry and not triclinic as do the simple crystals.

Brugnatelli * has described tetragonal crystals of potassium cyanate. They exhibit no cleavage, so are entirely distinct from our crystals.

ALLYL THIOCARBAMID.



(Prepared by W. Casamajor.)

Crystals prismatic in habit, usually singly terminated. Fig. 6 is an orthographic projection of such a crystal.

Monoclinic:

$$a : b : c = 0.9184 : 1 : 2.0044\,;\ \beta = 83°4'.$$

Observed forms:

$$c\{001\}\quad m\{110\}\quad t\{012\}\quad q\{011\}\quad r\{\bar{1}01\}\quad o\{\bar{1}11\}.$$

* *Ber. d. d. Chem. Ges.*, 27, 837, 1894. Abstr. *Zeit. f. Kryst. u. Min.*, 26, 628, 1896.

			Measured.		Calculated.	
mm'''	(110 : $1\bar{1}0$)	(11)	*84°	43′		
cr	(001 : $\bar{1}01$)	(10)	*59	45		
ct	(001 : 012)	(3)	*44	51		
mm'	(110 : $\bar{1}10$)	(6)	95	17	95°	17′
$m'c$	($\bar{1}10$: 001)	(4)	73	22		
or	($\bar{1}11$: $\bar{1}01$)	(5)	41	0		
$m'r$	($\bar{1}10$: $\bar{1}01$)	(3)	63	17		
mm	(110 : $1\bar{1}0$)	(3)	33	34	33	16
qt	(011 : 012)	(3)	17	41	18	28

Twins: (1) Twinning plane *c*. Have apparent hemimorphic orthorhombic symmetry. Fig. 7 (an orthographic projection with *c*, the twinning plane as the plane of projection).

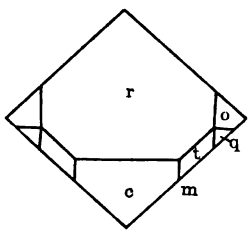


FIG. 6.

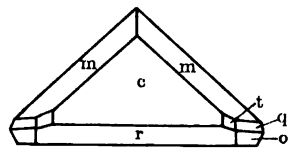


FIG. 7.

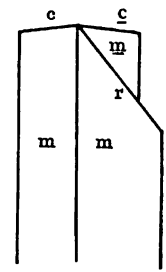


FIG. 8.

(2) Twinning plane *a*. Penetration twins resembling Carlsbad twins of orthoclase. There is an unequal development of the corresponding faces of the two individuals as indicated in Fig. 8.

ACETOXIME, $(CH_3)_2C:NOH$.

(Prepared by A. Metzger.)

Acetoxime crystallizes in the hexagonal system, the crystals resembling the common type of quartz crystals (see Fig. 9).

Good crystals were obtained by allowing a specimen tube containing them to stand for some time when sublimed crystals were found on the sides of the tube. As the crystals deliquesce very rapidly in the air measurements were made with the crystals enclosed in a hollow cylinder * with calcium chlorid.

Hexagonal:

$$c = 0.6541.$$

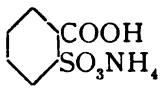
Observed forms:

$$m\{10\bar{1}0\} \qquad r\{10\bar{1}1\}.$$

*See Moses: "Characters of Crystals," p. 73, Fig. 74.

			Measured.	Calculated.
mr	(10$\bar{1}$0 : 10$\bar{1}$1)	(18)	52° 56′	
mm′	(10$\bar{1}$0 : 01$\bar{1}$0)	(15)	60 2	60° 0′

ACID AMMONIUM O-SULPHOBENZOATE,



The crystals of this salt are tabular, being flattened parallel to the basal pinnacoid and are rhombic in outline (Fig. 10).

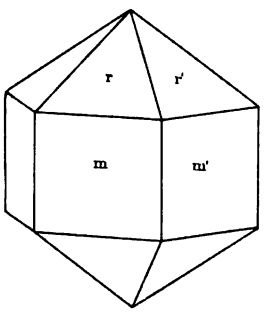


FIG. 9.

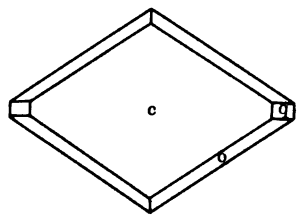


FIG. 10.

Orthorhombic:

$$a : b : c = 0.6691 : 1.12158.$$

Observed forms:

$$c\{001\}\ q\{011\}\ o\{111\}$$

			Measured.	Calculated.
co	(100 : 111)	(12)	*65° 25′	
oo‴	(111 : $\bar{1}$11)	(10)	*60 46	
oo^{IV}	(111 : 1$\bar{1}$1)	(3)	49 15	49° 10′
cq	(001 : 011)	(6)	50 28	50 29

Cleavage, perfect parallel to *c*.

MERCURIC OXYCYANID.

Crystals of two habits: (1) Obtuse sphenoidal with *o*{111} dominant, (2) prismatic, with *a*{100} dominant; *f*{201}, *o*{111}, and *c*{001} are inconspicuous. Fig. 11, an orthographic projection, represents both habits.

Tetragonal. Scalenohedral class:

$$= 0.4592.$$

Observed forms :

$a\{100\}$ $c\{001\}$ $f\{201\}$ $o\{111\}$ $o_1\{1\bar{1}1\}$.

			Measured.		Calculated.	
aa'	(100 : 010)	(12)	90°	2′	90°	0′
oo'	(111 : $\bar{1}11$)	(18)	*66°	0		
oo''	(111 : $1\bar{1}1$)	(6)	134	44	134	42
af	(100 : 201)	(3)	47	30	47	36
oo_1'	(111 : $1\bar{1}1$)	(11)	45	19½	45	18

Benzyl Sulfocyanid, $C_6H_5CH_2SCN$.

Crystals somewhat tabular parallel to a. The merohedral development of the q faces may be accidental. Fig. 12 is an orthographic projection with 010 as the plane of projection.

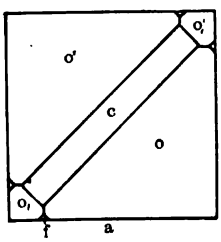


Fig. 11.

Monoclinic :

$a : b : c = 0.9019 : 1 : 0.7969$; $\beta = 83° 43'$.

Observed forms :

$a\{100\}$ $c\{001\}$ $m\{110\}$ $q\{011\}$.

			Measured.		Calculated.	
mm'''	(110 : $\bar{1}10$)	(10)	*83°	45′		
mc	(110 : 001)	(4)	85	45	85°	19½′
ac	(100 : 001)	(10)	*83	43		
am	(100 : 110)	(7)	48	15	48	7½
cq	(001 : 011)	(5)	*38	23		
mq	(110 : 011)	(3)	58	37	58	58

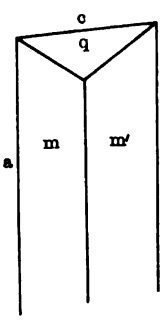


Fig. 12.

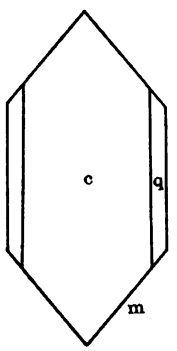
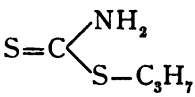


Fig. 13.

No cleavage was observed.

N-PROPYL DITHIOCARBAMID,



(Prepared by M. T. Bogert.)

Crystals tabular parallel to basal pinacoid and elongated in the direction of the *a* axis (Fig. 13).

Monoclinic:

$$a:b:c = 0.8536:1:0.9447;\ \beta = 77°\ 7'.$$

Observed forms:

$$c\{001\}\ a\{100\}\ m\{110\}\ t\{012\}\ q\{011\}.$$

			Measured.		Calculated.	
mm'''	$(110 \wedge 1\bar{1}0)$	(7)	*100°	28′		
cm	$(001 \wedge 110)$	(6)	*80	8		
cq	$(001 \wedge 011)$	(6)	*43	38½		
$c'm$	$(00\bar{1} \wedge 110)$	(3)	99	53½	99°	52′
qq'''	$(011 \wedge 01\bar{1})$	(4)	94	44	94	43
ct	$(011 \wedge 012)$	(3)	24	45	24	43

Cleavage perfect parallel to *c*, imperfect fibrous parallel to *a*.

[Contribution from the Havemeyer Laboratories of Columbia University, No. 63.]

A STUDY OF THE QUANTITATIVE DETERMINATION OF ANTIMONY.

BY LEWIS A. YOUTZ.

PART I.

VOLATILITY OF ANTIMONY CHLORIDES AND TIN CHLORIDES IN CONCENTRATED HYDROCHLORIC ACID.

The vaporizing temperature of dry arsenious chloride is 134°, antimonious chloride, 223°, and stannic chloride is 114°. These wide differences of boiling points, and the ease with which arsenic may be distilled over in the well-known Fischer's distillation of arsenic suggested the following work on the separation of antimony and tin.

In the course of the work it was soon noted that the volatilizing

temperature of the chlorides in a water solution of hydrochloric acid is not that of the dry chloride salt. In the case of tin the temperature at which the stannic chloride goes over in the aqueous hydrochloric acid solution is approximately that of the boiling point of dry stannic chloride, *i. e.*, 114° C., as shown by the results given below. Antimonious chloride, however, goes over at a temperature much below that of 223° C. In fact it begins going over where the boiling point of aqueous hydrochloric acid becomes constant, *i. e.*, at about 108° C. The arsenious chloride goes over at even a lower temperature than this, as it begins to go over as soon as the acid gas begins to leave the solution rapidly at about 75° C. to 80° C. for concentrated acid, or even below this temperature. There seems to be a misconception here on the part of some chemists regarding the volatilizing point of arsenious chloride in aqueous hydrochloric acid. In a recent edition (1901) of Prescott and Johnson's "Qualitative Analysis" in the temperature of the volatilization of the arsenic in the usual Fischer's distillation is given at 132° C., and Janhasch * gives the temperature as 134° C. This latter is the boiling point of dry arsenious chloride. However it is impossible to get so high a temperature as 134° C. for aqueous hydrochloric acid at the ordinary atmospheric pressure. It boils, beginning at about 35° C., the temperature rising gradually till at about 107°–108° C., the temperature for New York city remains constant, and the per cent. of acid here remains constant at about 20 per cent. acid until the whole solution is evaporated. This is in accord with the well-known fact that water containing hydrochloric acid, hydrobromic acid, or hydriodic acid cannot be completely freed from the acids by boiling, as after a time as the boiling proceeds, the relative amounts of acid and water remains constant for each acid. It was found that the addition of ferrous sulphate in such quantities as is customary in Fischer's distillation method for arsenic has but little effect on the boiling point of the solution, raising it only three or four degrees and of course not affecting the temperature of the vapor. Remsen † gives the temperature at which the arsenic begins to go over as 100° C. Schneider ‡ who first suggested this method of distillation, also gives the temperature as 100° C.

* "Gewichts Analyse" (1897), p. 176.

† "Inorganic Chemistry," p. 317, 1898.

‡ *Wein. Acad. Ber.* VI., 409, 1851.

Experimental.

In order to test the method of distillation of antimony and tin chlorides, a certain amount of the chloride was measured into a side-necked distilling flask fitted with a condenser, and a two-hole stopper with two thermometers, one thermometer reaching into the boiling solution to record the temperature of the liquid, and the other reaching to the level of the exit tube to measure the temperature of the vapor. The solution of the chlorides, to which was added from 50 c.c. to 150 c.c. of concentrated hydrochloric acid, was distilled in fractions, each fraction distilling over being collected in a vessel containing water and tested for antimony or tin by sulphuretted hydrogen gas. 25 c.c. or 50 c.c. of a standard approximately tenth normal solution of either antimony or tin (calculated to the metal) were taken for each experiment. In the case of stannous chloride, however, the temperature only of the vapor was recorded and a much larger quantity of the salt was taken for each distillation. The results for the four salts, *i. e.*, stannous chloride, antimonious chloride, and antimonic chloride are tabulated below.

Experiment 1. — Stannous Chloride.

100 c.c. of $n/10$ stannous chloride (pure Kahlbaum's) were taken, 150 c.c. of concentrated hydrochloric acid added, also a large portion of zinc chloride, and the distillation proceeded with. The temperature of the vapor rose gradually to 107°–108° and no tin was found in the distillate. The distillation was continued till the vapor showed a temperature of 150° C., when only a nearly dry salt remained in the flask. This distillate showed some tin, though only a very small fraction of the amount taken. The tin distilled was in the stannic condition.

Experiment 2. — Stannous Chloride.

In this experiment several grams of metallic tin were placed in a flask with about the same amount of strong hydrochloric acid as in the previous experiment, this allowed to act for some time, then zinc chloride added and the distillation carried out as in experiment 1. Little more than traces of tin distilled over and these only when the vapor temperature rose to 110°–115°. The tin in the distillate was in the stannic condition.

Experiment 3. — *Stannic Chloride.*

25 c.c. of $n/10$ stannous chloride solution was first treated with potassium chlorate and large excess of hydrochloric acid, then zinc chloride was added and more hydrochloric acid. The results of the distillation were as follows:

Fraction.	B. P. Liquid.	Vapor Temp.	Tin Found by H_2S in the Distillate.
1	110°–111°	107°–107.5°	Nothing.
2	112 –114	107 –108	"
3	114 –117	108	"

From this point a stream of hydrochloric acid gas was run through the boiling solution.

Fraction.	B. P. Liquid.	Vapor Temp.	Tin Found by H_2S in the Distillate.
4	117°–125°	108°	Nothing.
5	125 –185	111	Heavy precipitate of SnS_2.
6	185 –220	110 –108°	" " "

More hydrochloric acid (concentrated) was added and the distillation continued with a stream of hydrochloric acid gas.

Fraction.	B. P. Liquid.	Vapor Temp.	Tin Found by H_2S in the Distillate.
7	120°–162°	108°	Considerable SnS_2.
8	162 –185	109 ·	" "
9	185 –195	105 –108°	" "

The residue in the flask was here treated, after dilution with water, with hydrogen sulphide. Not over half of the stannic chloride had been distilled over, and what went over was mostly in the fifth and sixth fractions.

Experiment 4. — *Stannic Chloride.*

This was tried to determine the effect of sulphuric acid. Stannous chloride (25 c.c. $n/10$ solution), was oxidized by aqua regia, a large excess of concentrated hydrochloric acid added, then 25 c.c. of strong sulphuric acid. No stannic chloride distilled over after repeated distillations. Temperature as high as 220° C. Stannic sulphate remained as a non-volatile product.

Experiment 5. — *Antimony in Antimonic Condition.*

25 c.c. of the antimonious chloride ($n/10$) solution were taken and oxidized by nitric acid and excess of hydrochloric acid.

Fraction.	B. P. Liquid.	Temp. Vapor.	Antimony Found by H_2S in Distillate.
1	111°–112°	125°–106°	Nothing.
2	112 –119	106 –107	"
3	119 –125	107	"
4	125 –130	107	"
5	130 –145	107	"
6	145 –185	107 –108	Trace.

Experiment 6. — Antimony in Antimonic Condition.

The same amount of antimony solution as in experiment 5, oxidized by aqua regia, and excess of hydrochloric acid, then large amounts of zinc chloride added to raise the boiling point.

Fraction.	B. P. Liquid.	Temp. Vapor.	Antimony Found by H_2S in Distillate.
1	106°	100°	Nothing.
2	106°–110°	100 –106°	"
3	110 –117	106 –106.5	"
4	117 –145	106.5–107	"
5	145 –185	107 –108	Trace.
6	185 –275	108 –115.5	Just enough to see the ppt.

Experiment 7. — Antimony in Antimonic Condition.

To the residue of experiment 6, more hydrochloric acid was added and then the distillation carried on with a stream of hydrochloric acid gas.

Fraction.	B. P. Liquid.	Temp. Vapor.	Antimony in Distillate.
1	120°–145°	107°	Nothing.
2	145 –185	108	Trace.
3	185	112	"

Experiment 8. — Antimony in Antimonic Condition.

10 grams of antimonious chloride (the dry salt) were taken, several grams of potassium chlorate and a large excess of hydrochloric acid were added and distilled.

Fraction.	B. P. Liquid.	Temp. Vapor.	Antimony in Distillate.
1	112°	107°	Trace.
2	113	108	"
3	113	108	Nothing.

Experiment 9. — Antimony in Antimonic Condition.

Zinc chloride and more concentrated hydrochloric acid added to the residue of experiment 8, and the distillation repeated.

Fraction.	B. P. Liquid.	Temp. Vapor.	Sb in Distillate.
1	108°–110°	107.5°	Trace.
2	110 –111	108	Nothing.
3	111 –120	108	"
4	120 –130	108–109	Trace.
5	130 –155	109–111	Slight ppt.
6	155 –210	111	"

Experiment 10.— Antimonious Chloride.

25 c.c. of $n/10$ solution of antimonious chloride were taken, a large quantity of concentrated hydrochloric acid added, and then zinc chloride.

Fraction.	B. P. Liquid.	Temp. Vapor.	Sb in Distillate.
1	100°–110°	104°	Nothing.
2	110 –112	104 –107°	Trace.
3	112 –115	107 –108	"
4	115 –120	108	Distinct ppt.
5	120 –130	108	Larger "
6	130 –145	109	Much "
7	145 –210	110	" more "

During the seventh fraction a stream of hydrochloric acid gas was led through. Now additional concentrated acid was added and the distillation repeated with a stream of hydrochloric acid.

Fraction.	B. P. Liquid.	Temp. Vapor.	Sb in Distillate.
8	115°–125°	107°	Considerable ppt.
9	125 –145	108.5	" "
10	145 –170	112	" "

The combination of all the fractions in the above experiment showed that about two thirds or three fourths of the antimony had been distilled over, and by continued distillations with zinc chloride probably all would finally have been carried over.

Experiment 11.— Antimonious Chloride.

50 c.c. of the $n/10$ stock solution of antimonious chloride with the usual large amount of hydrochloric acid were taken, and in the latter part of the distillation a gram of sodium chloride was added.

Fraction.	B. P. Liquid.	Temp. Vapor.	Sb in Distillate.
1	110°	108°	Trace.
2	110	108	"
3	110	108	"
4	110	108	Little more than trace.

More hydrochloric acid here added and distillation continued in a stream of hydrochloric acid gas.

Fraction.	B. P. Liquid.	Temp. Vapor.	Sb in Distillate.
5	110°	108°	Trace.
6	110	108	"
7	110	108	"

More hydrochloric acid added and one gram of sodium chloride.

Fraction.	B. P. Liquid.	Temp. Vapor.	Sb in Distillate.
8	110°	108°	Trace.
9	110	108	"

Zinc chloride added with more acid and distillation continued.

Fraction.	B. P. Liquid.	Temp. Vapor.	Sb in Distillate.
10	110°–112°	108°	Trace.
11	112 –115	108	More than trace.
12	115 –125	108.5	Distinct ppt.
13	125 –150	111	Large ppt.

Experiment 12. — Antimonious Chloride.

25 c.c. *n*/10 antimonious chloride solution taken in a large amount of hydrochloric acid as usual, then one gram of sodium chloride added.

Fraction.	B. P. Liquid.	Temp. Vapor.	Sb in Distillate.
1	110°	107°	Nothing.
2	110	107	"
3	110	107	"

Here zinc chloride was added and more acid.

Fraction.	B. P. Liquid.	Temp. Vapor.	Sb in Distillate.
4	110°	107°	Nothing.
5	111	108	Trace.
6	111–115 (Stream HCl)	108	"
7	115–120 " "	108–108.5	Distinct ppt.
8	120–125 " "	108.5	Large ppt.

Experiment 13. — Antimonious Chloride.

Took 25 c.c. of a 1 per cent. solution of antimonious chloride, added 50 c.c. of concentrated sulphuric acid, and 20 c.c. of concentrated hydrochloric acid. The liquid began boiling at 70° and rose rapidly to 117°. The vapor at this point was 100°. Time 2 or 3 minutes. No antimony had distilled over up to this point. Results from this stage on are as follows :

Fraction.	B. P. Liquid.	Temp. Vapor.	Sb in Distillate.
1	122°	108°	Traces.
2	130	107.5	Slight pp.
3	150	105	Larger "
4	175	105–104–105	Same.
5	200	106	Trace.
6	220	104.5	Nothing.
7	260	123	"

In all .0150 gram of antimony (calculated as metallic Sb) had distilled over up to this point. Now 50 c.c. more of hydrochloric acid were added and the distillation repeated.

Fraction.	B. P. Liquid.	Temp. Vapor.	Sb in Distillate.
1	98°	90°	Nothing.
2	117	106	Trace.
3	125	108	Slight ppt.
4	145	107	Larger ppt.
5	175	107–104–106	Less ppt.
6	220	105	Merest trace.

Experiment 14. — Arsenious Chloride.

One gram of arsenious oxide, dissolved and oxidized by HCl and potassium chlorate was taken. Some zinc chloride added, then 15 grams of ferrous sulphate, and the distillation conducted with a stream of HCl gas.

The arsenious chloride began going over below 100° and at no time did the temperature rise above 112° for the liquid, and 108° for the vapor. After forty minutes all but a trace of the arsenic had distilled over.

DISCUSSION OF RESULTS.

Experiments 1 and 2 show that stannous chloride is entirely non-volatile up to a temperature of 150°, the traces of tin salt found in the distillate being in the stannic condition. This was doubtless due to oxidation of a small portion of the stannous chloride by the oxygen contained in the air in the flask, and in the water used to make the solution.

From experiments 5, 6, 7, 8, 9, when antimony was distilled after oxidation by either nitric acid or potassium chlorate, it is seen that no antimony distils over till a temperature of 145° for the liquid and 108° for the vapor, the maximum for aqueous hydrochloric acid, is reached, and that even at considerably higher temperatures than this but little more than traces go over. It should be mentioned that when a temperature of 145° was reached in the liquid, only a very small amount of hydrochloric acid and water remained in the flask, the liquid being a very concentrated solution of the antimony, and the vapor having reached its maximum for aqueous hydrochloric acid from this point rose in temperature above this maximum.

The non-volatility of the antimony when oxidized to the pentad form is undoubtedly due to the formation of some one of the anti-

monic acids by hydrolysis of the antimonic chloride presumably first formed by the oxidizing agent, as shown by the following reaction:

$$SbCl_5 + 4H_2O = H_3SbO_4 + 5HCl.$$

Antimony pentachloride formed by the treatment of metallic antimony by excess of dry chlorine gas is very volatile, distilling at a considerably lower temperature than the trichloride, and at the same time partially decomposing into the trichloride and free chlorine. If the pentachloride, however, is treated with excess of water, it forms a non-volatile solution, just as the solution of antimony made with hydrochloric acid and nitric acid, or potassium chlorate. This disposition to form an acid when oxidized to its highest state finds an analogy in phosphorus and arsenic, these forming in aqua regia phosphoric acid, and arsenic acid respectively. The same property is shown in bismuth, though in this case bismuth is so metallic in its properties that it is not oxidized to the pentad form in acid solution with aqua regia, or potassium chlorate. However, in alkaline solution, if free chlorine gas is added to the bismuth compound, bismuthic acid is formed, $HBiO_3$. So here we have the analogy of all the elements of this periodic group when oxidized to the highest state in aqueous solution hydrolyzing to the acid, the tendency gradually decreasing from phosphorus down to bismuth, where it is almost lost.

The non-volatility cannot be due to the formation of a double chloride salt with potassium chloride as is stated by some chemists,* as in experiment 5 the temperature of volatilization was the same as in the other experiments where potassium chlorate was used as the oxidizing agent, and here no alkaline chloride was present to form a double chloride. The slight volatility of the antimony at the beginning of the distillation in experiments 8 and 9 was doubtless due to the incomplete oxidation of the large amount of antimony taken so that part was in the form of the trichloride, which at that temperature, as shown by the other experiments, is volatile.

From the results in experiment 3 it is seen that the stannic chloride volatilizes only when the temperature of the vapor rose above the boiling point of the dry salt. This vapor temperature was reached only when the temperature of the liquid reached somewhere between 125° and 185° C. The presence of hydrochloric

* Clowes and Coleman's "Quantitative Analysis," p. 270, 3d ed.

acid seems to have no effect on the volatility of the stannic chloride. In experiment 4 it seems that the sulphuric acid converts the stannic chloride to a sulphate which is non volatile at the temperatures of the experiment.

Experiments 10–13. The antimony in the trivalent form as chloride simulates arsenious chloride as to its volatility in aqueous hydrochloric acid, but is driven over much less rapidly and at a somewhat higher temperature, as is seen by referring to experiment 14. Traces of antimony distilled over as soon as the temperature of the solution arose to the maximum for aqueous hydrochloric acid, but only in traces till the temperature of the liquid rose rapidly, and after the vapor had reached the point where its temperature began to rise above that of the maximum for aqueous hydrochloric acid.

In experiment 13, where sulphuric acid was added to raise the temperature, antimony distilled over slowly till practically all the hydrochloric acid had been driven over, and only antimony and sulphuric acid remained in the flask. The antimony then ceased to distil over, doubtless because of the formation of the sulphate of antimony which is non-volatile at the temperature attained. On the addition of a second portion of hydrochloric acid to the residue and redistilling, the antimony went over again as in the first distillation, it ceasing again to distil as soon as the hydrochloric acid had been boiled out. From this it would seem that the antimony in the experiment, when in the presence of strong hydrochloric acid, is in the form of a chloride, the condition as chloride or sulphate depending on which acid is in excess, thus obeying the law of mass action.

Conclusions.

1. No *practical* analytical separation of antimony and tin can be effected by distillation.

2. Antimony oxidized by nitric acid or by potassium chlorate in aqueous hydrochloric acid solution is totally non-volatile at the boiling point of aqueous hydrochloric acid, due probably to the formation of antimonic acid.

This work was undertaken at the suggestion of Prof. Edmund H. Miller and carried out under his direction.

UPON THE STRUCTURE OF THE STARCH MOLECULE.

By F. E. HALE.

To suggest a starch molecule which will satisfy the results of all the workers upon starch is practically an impossibility. The best that can be attempted is to satisfy the work which seems to be most reliable. Some of the results have been obtained by such different methods that they can hardly be compared. The better to present the problem a brief history of the ideas of starch structure which have hitherto prevailed needs no excuse.

The original idea of the action in the hydrolysis of starch was that dextrin was produced from starch and sugar from dextrin. Musculus,* in 1860, first advanced the theory, now generally accepted, that the production of dextrin and of sugar was simultaneous. Some years later, in 1878, Musculus and Grüber† recognized the fact that it was difficult to hydrolyze more than 51–52 per cent. of starch to sugar on a basis of dextrose and, after corroborative experiments of their own, adopted O'Sullivan's‡ discovery that maltose was the sugar produced. Up to the disappearance of the iodine color reaction with the products the hydrolysis of starch by diastase is very rapid. It becomes checked then, they believed, by the presence of the products of hydrolysis. They thought that the fact that some of the dextrins produced were not attacked by diastase overthrew the old idea of the formation of sugar through the intermediate production of dextrin. They believed that their own bodies were not identical with Bondonneau's,§ but that both his and theirs were real products of the hydrolysis of starch, produced by a series of hydrolytic reactions which resulted in the formation of dextrins of constantly decreasing molecular weight. They came to the conclusion that starch itself is a polysaccharide of at least the size, $(C_{12}H_{20}O_{10})_{5-6}$.

O'Sullivan,‖ in 1879, claimed that the dextrins produced from starch all have the same rotatory power, and that it is the same as

* *Ann. Chim.*, III., 60, 203; IV., 6, 177.

† *Bull. Soc.*, 30, 54.

‡ *Jour. Chem. Soc.*, 25, 579–588.

§ *Ber. Chem. Gesell.*, 3 B, 9, 6 and 69.

‖ *Jour. Chem. Soc.*, 35, 770.

that of soluble starch $(\alpha)_j = 222° +$, that they all have no reducing power, and that starch and the final dextrin have the same specific gravity. He suggested that the differences between starch and the dextrins are due to the "relation and the arrangement of the molecules to one another, probably in solution alone." He concluded that starch at least equals $(C_{12}H_{20}O_{10})_6$.

In the same year, Herzfeld* advanced a theory along the old line, not a splitting of the starch molecule, but a conversion of starch into soluble starch, erythrodextrin, and achroödextrin successively, and a splitting of the last body into maltodextrin and maltose. Below 65° maltose and achroödextrin were formed by diastase, and above 65° erythrodextrin and maltodextrin as well. He suggested for maltodextrin the formula $(C_{18}H_{32}O_{16})$. The most significant feature of his work is the discovery of maltodextrin, a body combining the properties of maltose and dextrin.

Brown and Heron,† in 1879, agreed with Musculus and Grüber in considering starch a polysaccharide which breaks down by hydrolysis, splitting off maltose at every step and thus forming a series of dextrins of constantly decreasing size. The final dextrin would most naturally be $(C_{12}H_{20}O_{10})_2$, and as they had found that a stable dextrin hard to break down into maltose by diastase, was formed when four fifths of the starch had been hydrolyzed to maltose, they concluded that the starch molecule was at least five times as large as this final dextrin. Hence they suggested the formula for starch, $(C_{12}H_{20}O_{10})_{10}$. At each splitting $C_{12}H_{20}O_{10}$ comes off and is hydrolyzed to maltose. They agreed with O'Sullivan in concluding that the pure dextrins all have the same rotation, that of soluble starch, and have no reducing power. To soluble starch they gave the rotation $(\alpha)_j = 218°$.

In 1885, Brown and Morris‡ modified the view just set forth to agree with later discoveries. They had found among the products of hydrolysis of starch a body always present which resembled, but was not identical with, Herzfeld's maltodextrin, to which they gave the formula $(C_{12}H_{20}O_{10})_2 C_{12}H_{22}O_{11}$. Because of the difficulty of hydrolyzing the final dextrin they suggested for starch the formula $5(C_{12}H_{20}O_{10})_3$, that is, five amylin groups, as they called

* *Ber. Chem. Gesell.*, 12, 2120.

† *Ann. Chem.*, 199, 165.

‡ *Ann. Chem.*, 231, 72.

them, four arranged about a fifth symmetrically. At each splitting $(C_{12}H_{20}O_{10})_3$ comes off and forms maltodextrin, thus:

$$\underset{\text{Starch.}}{5(C_{12}H_{20}O_{10})_3} + H_2O = \underset{\text{Dextrin.}}{4(C_{12}H_{20}O_{10})_3} + \underset{\text{Maltodextrin.}}{(C_{12}H_{20}O_{10})_2.C_{12}H_{22}O_{11}}, \text{ etc.}$$

Maltodextrin then splits into maltose completely.

In 1889,* while adhering to their previous grouping Brown and Morris increased yet more the size of starch to $5(C_{12}H_{20}O_{10})_{20}$, since they had determined the molecular weight of their residual dextrin to be $(C_{12}H_{20}O_{10})_{20}$. They considered starch to consist of five amylin groups, four arranged about a fifth, as before, thus:

$$(C_{12}H_{20}O_{10})_{20}.([C_{12}H_{20}O_{10}]_{20})_4.$$

The amylin groups split off one by one and are hydrolyzed to maltodextrins. The last amylin group is the stable dextrin. The first and last stages of the formation of these maltodextrins may be represented as follows:

$$\text{First, } \underset{\text{Amylin group.}}{(C_{12}H_{20}O_{10})_{20}} + H_2O = \underset{\text{A maltodextrin.}}{C_{12}H_{22}O_{11}.(C_{12}H_{20}O_{10})_{19}}.$$

$$\text{Last, } (C_{12}H_{20}O_{10})_{20} + 19H_2O = \underset{\text{A maltodextrin.}}{(C_{12}H_{22}O_{11})_{19}.C_{12}H_{20}O_{10}}.$$

These maltodextrins then split into smaller bodies and maltose. Two of these smaller bodies they have prepared, maltodextrin $(C_{12}H_{20}O_{10})_2.C_{12}H_{22}O_{11}$ and amylodextrin $(C_{12}H_{20}O_{10})_6.C_{12}H_{22}O_{11}$.

Lintner and Düll,† in 1891, revert somewhat to earlier lines of belief in thinking as did Herzfeld, that sugar splits from the last dextrin. They call starch a great complex molecule, amylodextrin the first product of hydrolysis and the simplest. Under the term amylodextrin they include all soluble starches. They believe that soluble starch splits into three molecules of erythrodextrin, and erythrodextrin into three molecules of achroödextrin. Achroödextrin splits into isomaltose and isomaltose changes to maltose. They believe that these changes take place simultaneously as well as in steps. They found the following molecular weights for their bodies by Raoult's freezing method:

Amylodextrin = $(C_{12}H_{20}O_{10})_{54}$, molecular weight = 17,496;
Erythrodextrin = $(C_{12}H_{20}O_{10})_{18}.H_2O$, molecular weight = 5,850;
Achroödextrin = $(C_{12}H_{20}O_{10})_6.H_2O$, molecular weight = 1,962;
Isomaltose = $C_{12}H_{22}O_{11}$ (apparently with H_2O).

* *Proc. Chem. Soc.*, 1889, 96; *Ber. Chem. Gesell.*, 24, 3, 723.

† *Ber. Chem. Gesell.*, 26, 2533.

Since, when about two thirds of the starch is hydrolyzed, the production of maltose does not increase comparatively, they think that when erythrodextrin divides to achroödextrin two molecules of the latter hydrolyze to isomaltose and then to maltose.

Johnson * gives forth the theory that acid splits off successively dextrose from the starch molecule yielding a series of glucoamylins, combinations of dextrose and dextrin, of decreasing molecular weight, the first of which are feebly attacked by diastase. The rotation and reduction powers of the mixed products and of the products precipitated by alcohol agree with the relation expressed by the formula

$$(\alpha)_{j3\cdot86} = 195^\circ - \frac{195^\circ - 52.8^\circ}{100} R.$$

He is the only investigator who has proposed a graphical formula for the starch molecule, but as it is formed by joining the aldehydic ends of dextrose together and the alcoholic ends together it cannot possibly be correct, since by hydrolysis maltose could not be produced, but a sugar similar to cane sugar or a sugar with an aldehydic group on each end such as is not known.

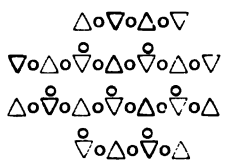
Scheibler and Mittelmeier † have made an attempt to build up a starch molecule theoretically from sugar. They classify the sugars according as they contain a carbonyl group (C = O) or not; for example, dextrose, levulose, milk sugar with such a group, cane sugar without such a group. They class granulose with the second class of sugars, since it is composed of groups with no carbonyl radicle. Characteristic reactions for granulose and bodies of the cane sugar type are the lack of power of potassium hydroxide to turn them brown, no reduction with Fehling's solution, no osazone products and hydrolysis to dextrose, or isomers, by the action of acid. Bodies of the milk sugar type are turned brown or yellow, by hot dilute potassium hydroxide, and show an aldehydic or ketonic nature by reducing Fehling's solution and by forming osazones. They are also hydrolyzed by acid to dextrose, or its isomers. Maltose, milk sugar, cane sugar, etc., have the formula $2C_6H_{12}O_6 - H_2O$; melitose and melicitose, $3C_6H_{12}O_6 - 2H_2O$. Granulose may then be represented by $n(C_6H_{12}O_6) - (n - 1)H_2O$. They distinguish two kinds of bonds, carbonyl and carbinol. By

* *Jour. Chem. Soc.*, 73, 490–502.

† *Ber. Chem. Gesell.*, 23, 2, 3060–3075.

the first a carbonyl group (C = O) is united with a carbinol group (COH), leaving a free carbonyl group; for example, milk sugar. By the second two carbonyl groups unite so that the product shows no reducing power and forms no osazone. They designate glucose groups by R_1, R_2, etc. The sign $<$ indicates an aldehydic group; $R <$ or $> R$ represents dextrose; milk sugar is $R_1 < R_2 <$; cane sugar $R_1 <> R_2$. Granulose may be represented between two limits, $R < R < R < R < \cdots R < R < > R > R \cdots > R > R > R > R$ and $R < R < R < R < R < R < \cdots R < R < > R > R$. Hydrolysis of these bodies would yield dextrin, reducing or non-reducing, and with or without sugar.

Syniewski* has lately put forth a theory which attempts an explanation for the existence of all the various kinds of products found in the hydrolysis of starch. He considers starch to be a simple substance completely soluble at 138°. Soluble starches are numerous hydrolytic products of starch and from these soluble starches may be formed reversion products analogous to insoluble starch. He considers starch cellulose to be a true form of starch. All of these soluble starches and reversion products give a pure blue with iodine. None of them equal exactly $(C_6H_{10}O_5)_n$. These bodies do not reduce Fehling's solution. They are then products of carbinol hydrolysis. A body which reduces Fehling's solution must be formed by the breaking of a carbonyl bond with a carbinol, or an aldehydic group bound after the manner of an anhydride. Syniewski calls $(C_{18}H_{32}O_{16})_3$ amylogen in its simplest form and thinks that starch is composed of many amylogen groups bound together by carbinol anhydride connections thus:



"The molecule of starch and of all bodies between starch and the carbinol hydrolytic products of starch containing amylogen consist of a great continuous number of amylogen molecules which are bound together in an anhydride manner. These bonds are between carbinol groups.

---

* *Ann. Chem.*, 309, 282–315.

"The amylogen is in such manner bound together that in it are bound three maltose structures with an eighteen carbon atom dextrin structure. The dextrin structure consists of three glucose structures of which two are contained as isomaltose.

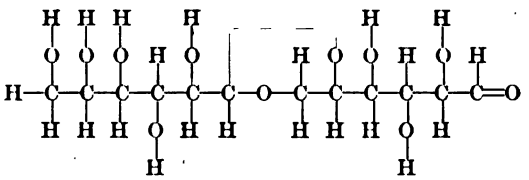
"By the hydrolysis of amylogen in the first case all the maltose molecules are split off one after the other and the dextrin residue remains. By further working of the malt extract the dextrin structure is split into isomaltose and glucose and the isomaltose finally also breaks into glucose."

The following various empirical formulæ have been proposed for starch, most of them intended for soluble starch:

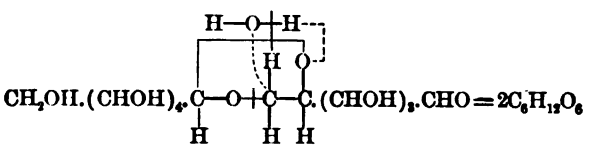
1836. $C_6H_{10}O_5$ — Early Authors. Payen, *Ann. Chim.*, II., 61, 355; II., 65, 225.
$C_{12}H_{20}O_{10}$ — Wider belief.
1872. $C_{18}H_{30}O_{15}$ — O'Sullivan, *Jour. Chem. Soc.*, 30, 125.
1881. $C_{24}H_{40}O_{20}$ — Pfeiffer and Tollens, *Ann. Chem.*, 210, 289.
1887. $C_{24}H_{40}O_{20}$ — Mylius, *Ber. Chem. Gesell.*, 20, 688.
1874 $C_{36}H_{62}O_{31}$ — Nägeli, *Beiträge zur näheren Kenntniss der Stärkegruppe*, 1874, 104.
1878. $(C_{12}H_{20}O_{10})_{5-6}$ — Musculus and Grüber, *Bull. Soc.*, 30, 54.
1879. $(C_{12}H_{20}O_{10})_6$ — O'Sullivan, *Jour. Chem. Soc.*, 35, 770.
1879. $(C_{12}H_{20}O_{10})_{10}$ — Brown and Heron, *Ann. Chem.*, 199, 165.
1885. $([C_{12}H_{20}O_{10}]_3)_5$ — Brown and Morris, *Ann. Chem.*, 231, 72.
1893. $(C_{12}H_{20}O_{10})_{54}$ — Lintner and Düll, *Ber. Chem. Gesell.*, 26, 2533.
1889. $([C_{12}H_{20}O_{10}]_{20})_5$ — Brown and Morris, *Proc. Chem. Soc.*, 1889, 96.
1899. $([C_6H_{10}O_5]_9)_n$ — Syniewski, *Ann. Chem.*, 309, 282.

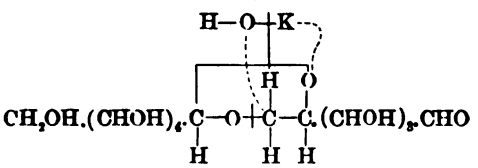
Nothing satisfactory can be conceived concerning the structure of starch without first knowing the structure of maltose. Maltose forms an ozazone with phenylhydrazine, and, therefore, has an aldehydic or ketonic group. As maltose splits to two molecules of dextrose that group must be aldehydic and maltose must be composed of two molecules of dextrose joined by one of the aldehydic groups. The natural supposition is that the two dextrose molecules join end to end, as weak oxidization does not split off groups containing a smaller number of carbon atoms than six, for maltose oxidizes to gluconic or saccharic acid, both of which have the structure of dextrose with its aldehydic group changed to a carboxyl group, the saccharic acid having its opposite end also

oxidized to a carboxyl group. Maltose also forms an octacetyl compound * and so has but eight hydroxyl groups which means that water has separated from two hydroxyl groups of dextrose in forming maltose. The only formula which seems to have a synthetic possibility is the following:



This formula has been suggested by E. Fischer and J. Meyer † and so has substantial reason for acceptance. The manner in which it might hydrolyze to dextrose may be represented in different ways. The lines crossing the linkings show where the latter break and the dotted lines show the new connections.

1. 

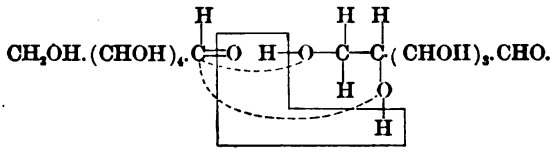
2. 

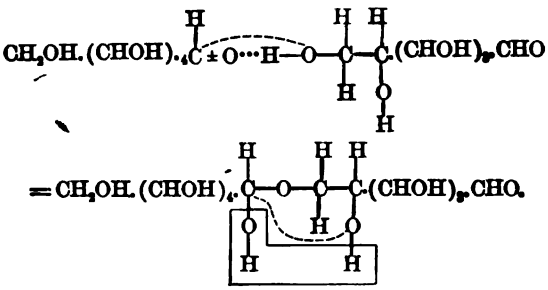
$$= C_6H_{12}O_6 + CH_2OH.CHOK.(CHOH)_3.CHO.$$

The action of acid may be similarly expressed. This formula possesses one alhehydic group and eight hydroxyls, the latter arranged according to E. Fischer's stereo-isomeric formula for dextrose. As a synthetic possibility two views may be considered. According to the first the aldehydic oxygen of one dextrose molecule oxidizes the end of the other dextrose molecule, and according to the second the two molecules join, in a measure, similarly to the aldol reaction, and then lose a molecule of water.

* Herzfeld, *Ber. Chem. Gesell.*, 13, 267; Ling and Baker, *Jour. Chem. Soc.*, 67, 212.

† *Ber. Chem. Gesell.*, 22, 1941.

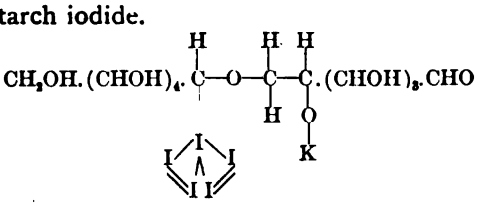
1. 

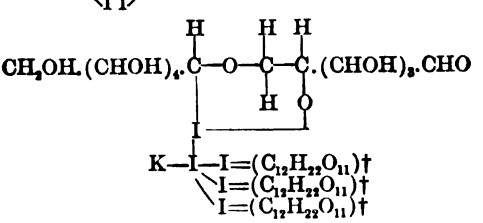
2. 

The second reaction differs from the aldol reaction only in that the hydrogen of a hydroxyl is transferred, and water splits off after the union of the two molecules of dextrose.

I have seen no attempt as yet to explain the manner of chemical union of iodine and of potassium iodide to the starch molecule in starch iodide. At least two methods of such union are possible. It seems probable that the union takes place at the point of dehydration since this must be one point of interunion between maltose nuclei in starch and hence would govern the amount of iodine possible to combine with the starch to form starch iodide. Pickering * states that starch iodide is far more stable than starch and that it will keep indefinitely if iodine be kept in excess. Such a fact likewise would imply that the iodine is joined to the maltose nuclei at the point of hydrolysis as well as of dehydration. The two possibilities are as follows:

The blue starch iodide.

1. 

2. 

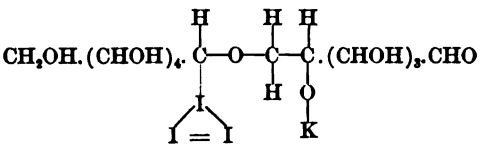
* *Chem. News*, 42, 311.

† The structure of these groups is like that of the one figured.

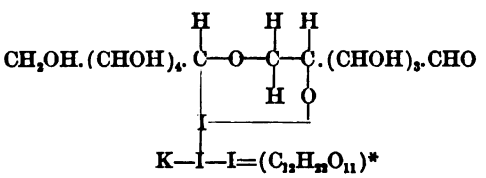
For convenience' sake maltose is used to illustrate the manner of union, as the linking in starch should not differ. In formula 1 the group $KI.I_4$ adds itself to the starch just as potassium hydroxide may be supposed to add itself when starch takes up alkali without hydrolizing. In formula 2 the four iodine atoms are bonded between the oxygen and carbon of four separate maltose nuclei in the starch and linked to the iodine atom of the potassium iodide.

The red starch iodide may be similarly represented thus:

1.



2.



For several reasons, which will be more apparent later, I prefer the second method of linking the iodine, especially because the starch iodide which Mylius† analyzed contained one atom of iodine to four $C_6H_{10}O_5$ groups and also a sodium compound of starch which Pfeiffer and Tollens'‡ analyzed contained one sodium atom to four $C_6H_{10}O_5$ groups. It is probable that the iodine is linked at first according to the first arrangement and then changes by intermolecular rearrangement to the second. There is much reason to believe that the linking by which two dextrose molecules unite to form maltose is repeated many times in forming the starch molecule. This linking corresponds to the linking which Scheibler and Mittlemeier§ termed mono-carboxylic, but to which they gave no graphical structure. There should be no hindrance to an increase in the ratio of iodine to starch in starch iodide beyond that which Mylius found. The reason that there is only one iodine atom for every four $C_6H_{10}O_5$ groups must be explained by the fact that the above anhydride linking, where the iodine would join on,

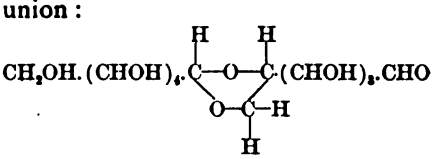
* The structure of this group is like that of the one figured.

† *Ber. Chem. Gesell.*, 20, 688.

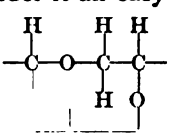
‡ *Ann. Chem.*, 210, 289.

§ *Ber. Chem Gesell.*, 23, 2, 3060–3075.

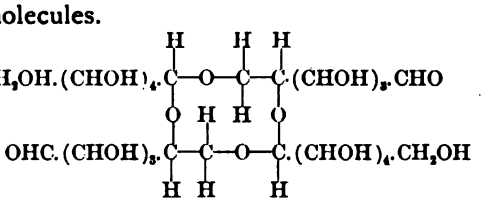
is used up many times in forming the starch molecule. Hence both Mylius' work and Pfeiffer and Tollens' work necessitates a larger starch molecule than they have adopted. It may be asked why maltose does not take up iodine in the same manner. The only explanation which suggests itself is that a maltose molecule may be arranged as Fischer represents it, so that there is no strain at the point of union:



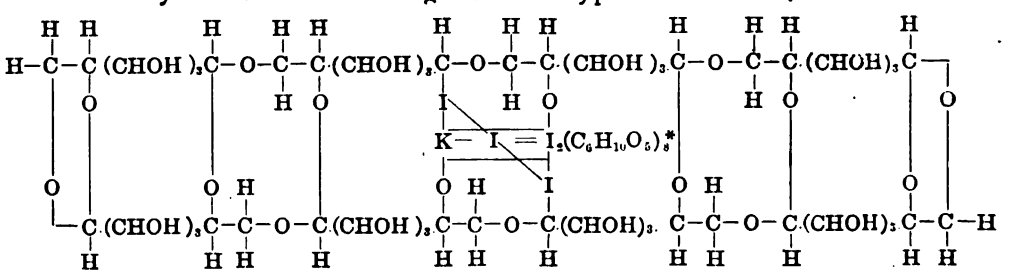
But in the starch molecule where many maltose groups are bound together in a line the tendency would be to produce a strain on the anhydride bond and to render it an easy point of attack, thus:



One method of joining together maltose molecules so that the anhydride bonds will be used up and yet produce no strain at any one point is the following; that is, by linking together two or more maltose molecules.



Mylius' starch iodide might then be typified as follows:



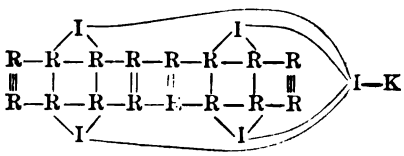
There are at least two ways of explaining the structure of Rouvier's † starch iodide and my own,‡ which contain one half and one

* The structure of this group is like that of the one figured.

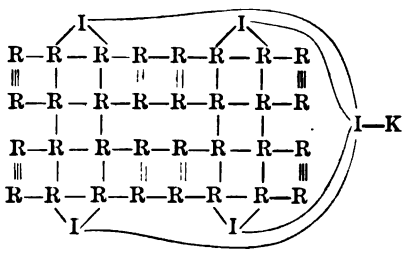
† *Comp. Rend.*, 114, 1366.

‡ *Amer. Chem. Jour.*, December, 1902, 438.

quarter the amount of iodine respectively that Mylius' body has: First, by supposing that a greater number of anhydride bonds are employed in binding together two lines of $C_6H_{10}O_5$ groups; or secondly, by joining together groups like that represented into a larger molecule. As my starch iodide was of a pasty consistency and would not filter, while Mylius' starch solution was filtered, the latter explanation seems best. Let R equal a $C_6H_{10}O_5$ group, then Mylius' body might be typified as follows:



So Rouvier's body might be represented thus:



My body would be composed of four groups bound together in a similar manner so that iodine could enter only on the outside rows as in Rouvier's body.

Girard * in 1887 determined the amounts of iodine absorbed by various starches and ascribed the varying results of the different species to absorption of iodine by the starch cellulose. It seems more probable, however, that he was really dealing with bodies grouped as the above. His rice starch absorbed 4.5 per cent., of iodine. My potato starch paste required 4.38 per cent. to 4.90 per cent. of iodine. Girard found the following percentages for various kinds of starch, 12.2 per cent., 9.8 per cent., 7.1 per cent., 6.95 per cent., 6.65 per cent., 5.9 per cent., 5.8 per cent., 5.25 per cent. and 4.5 per cent. Calculated closely these values would correspond to the following ratios:

12.2 per cent. = $(C_6H_{10}O_5)_{6.4}I$
9.8 per cent. = $(C_6H_{10}O_5)_8I$
7.1 per cent. = $(C_6H_{10}O_5)_{11}I$

* *Ann. Chim.*, VI., 12, 275.

6.95 per cent. = $(C_6H_{10}O_5)_{11.3}I$
6.65 per cent. = $(C_6H_{10}O_5)_{11.8}I$
5.9 per cent. = $(C_6H_{10}O_5)_{13.3}I$
5.8 per cent. = $(C_6H_{10}O_5)_{13.5}I$
5.25 per cent. = $(C_6H_{10}O_5)_{15}I$
4.5 per cent. = $(C_6H_{10}O_5)_{18}I$

As the determination of the percentage of iodine in starch iodide is influenced by various conditions it is not very reliable. In excess of iodine any dextrins present are included in the starch iodide precipitate, and in the presence of an excess of starch this excess is precipitated with the starch iodide, at least when the starch iodide is precipitated by sulphuric acid.* Hence the proportions may well be considered as approximate determinations neighboring to $(C_6H_{10}O_5)_4I$, $(C_6H_{10}O_5)_8I$, $(C_6H_{10}O_5)_{12}I$, $(C_6H_{10}O_5)_{16}I$, or mixtures. Calculated upon a basis of these related groups, the percentage of free iodine, that is, not including hydriodic acid, to the starch in starch iodide would be as follows:

$(C_6H_{10}O_5)_4I$ = 19.6 per cent. iodine to starch.
$(C_6H_{10}O_5)_8I$ = 9.8 " " " " "
$(C_6H_{10}O_5)_{12}I$ = 6.5 " " " " "
$(C_6H_{10}O_5)_{16}I$ = 4.9 " " " " "

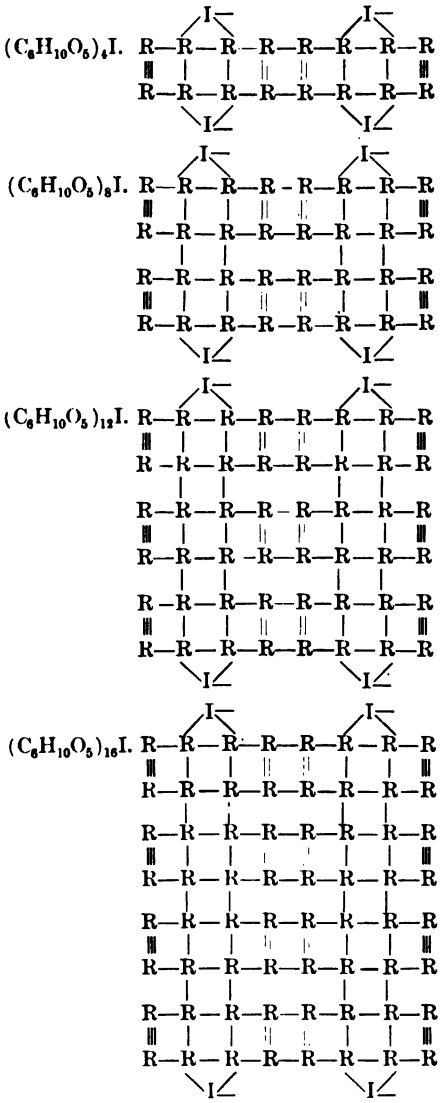
Referring these values back to the values obtained, the errors would be within the limits of experimental error. The following list includes also the results of analyses made by Bondonneau,† Rodewald and Kattein,‡ Seyfert,§ and Rouvier:

Mylius, Seyfert,	17 %–19.9 %. 18.56 %.	$(C_6H_{10}O_5)_4I$ = 19.6 %.
Bondonneau, Rodewald and Kattein,	14 %–15 %. 14.3 %–14.8 %	$2(C_6H_{10}O_5)_4I$ + $(C_6H_{10}O_5)_8I$ = 14.7 %.
Girard,	12.2 %	$2(C_6H_{10}O_5)_4I$ + $2(C_6H_{10}O_5)_8I$ = 13.06 %.
Rouvier, Girard,	8.57 %–9.12 %. 9.8 %.	$(C_6H_{10}O_5)_8I$ = 9.8 %.
Girard,	5.8 %–7.1 %.	$(C_6H_{10}O_5)_{12}I$ = 6.5 %.
Girard, Hale,	4.5 %–5.25 %. 4.38 %–4.9 %.	$(C_6H_{10}O_5)_{16}I$ = 4.9 %.

* These two facts I have found by experiment.
† *Comp. Rend.*, 85, 671.
‡ *Sitzungber. d. Berliner Akad.*, 1899, 2, 628.
§ *Zeitschr. Angew. Chem.*, 1888, 15.

There is also the possibility that mixtures of these bodies exist together and give intermediate values. If $(C_6H_{10}O_5)_{16}$ should not completely hydrolyze to $(C_6H_{10}O_5)_4$ it might most naturally split to one molecule of $(C_6H_{10}O_5)_8$ and two molecules of $(C_6H_{10}O_5)_4$. These proportions give, as seen in the table, 14.7 % of iodine, which value very closely agrees with Bondonneau's and Rodewald and Kattein's analyses. Girard's 12.2 % analysis might represent another simple mixture. A mixture of $2(C_6H_{10}O_5)_4$ and $2(C_6H_{10}O_5)_8$ would form a mixture of iodides with 13.06 % of iodine.

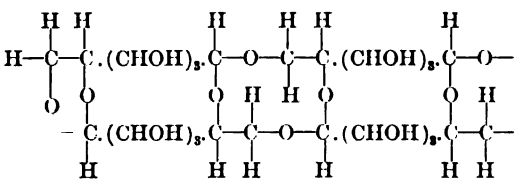
The above 4 bodies may be typified as follows:



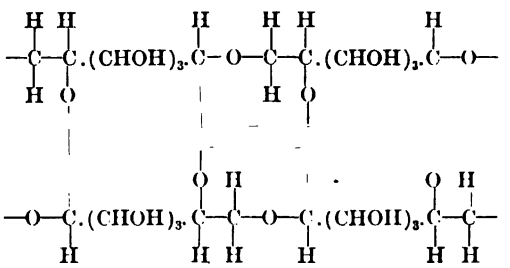
If we attempt to build up a complete starch molecule in keeping with the above principles Lintner and Düll's work offers the greatest opportunities. Syniewski's molecule may be readily represented graphically, but when one attempts to hydrolyze a complex molecule, builded up from his amyloin groups, most unnatural recombinations need to be assumed in order to explain the larger dextrins. Lintner and Düll's molecule is a large body, in keeping with Brown and Morris' work. Although its molecular weight was determined to be that of $(C_{12}H_{20}O_{10})_{54}$, yet it is probably the simplest soluble starch forming an iodide containing iodine in the ratio which Mylius found. If we let R be a $(C_6H_{10}O_5)$ group, as previously, then for Lintner and Düll's soluble starch, I would suggest the accompanying graphical structure: (See opposite page.)

The linkings at different portions of the chain may be represented graphically as follows:

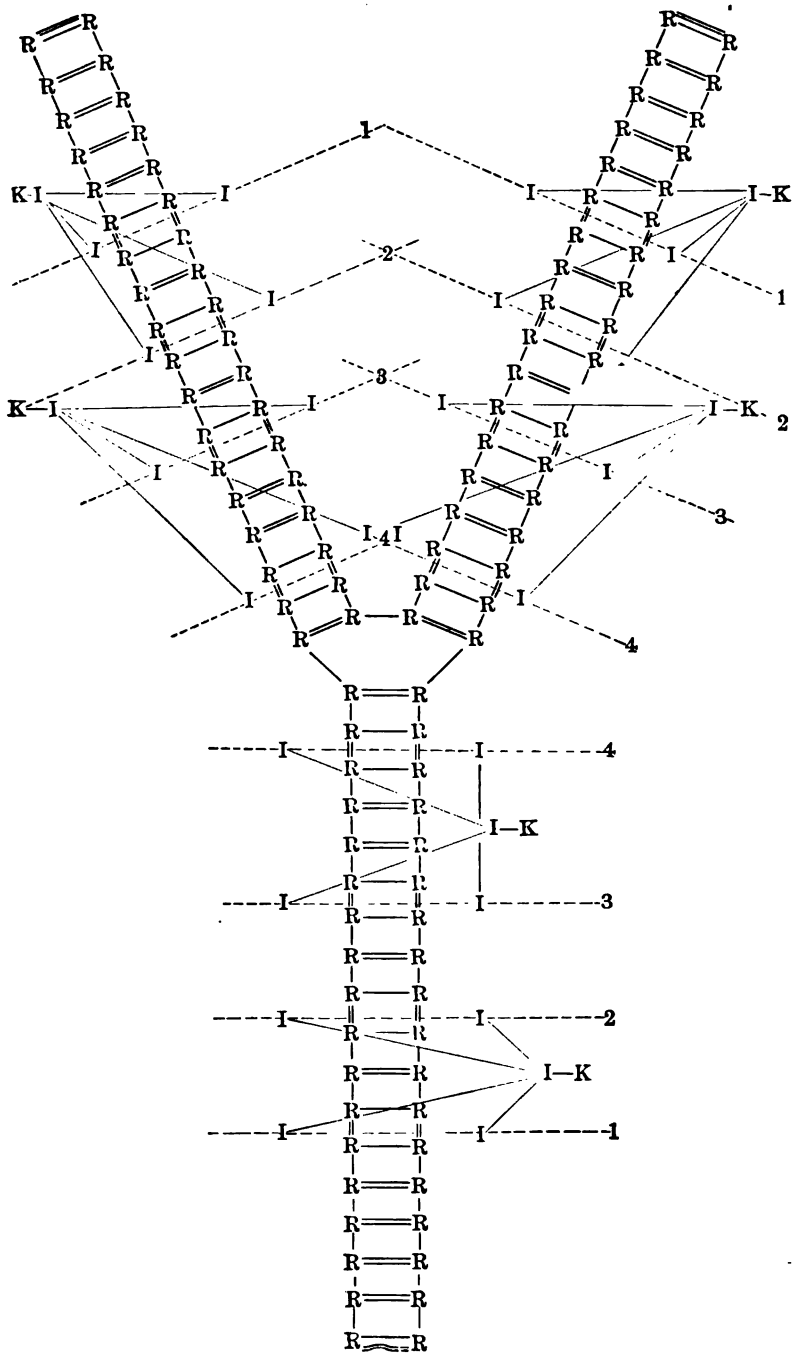
The end of a chain:

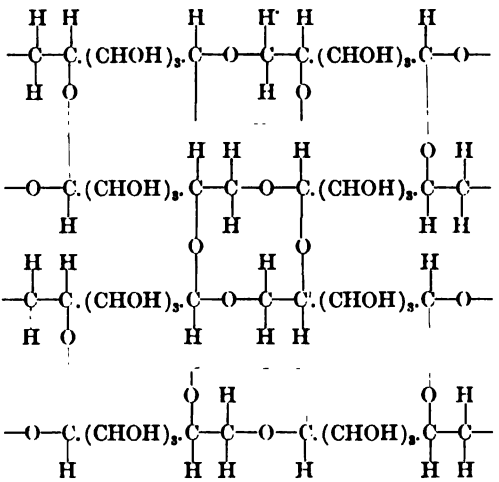


Where iodine joins on, and hydrolysis first takes place:

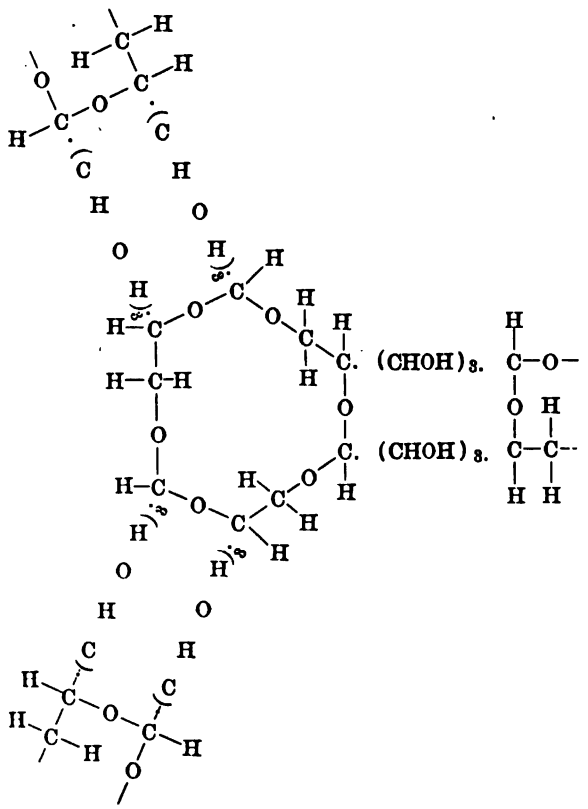


Where two, three, or four of the smaller bodies join to form the more insoluble starches of Rouvier, Girard and myself:


1
2
3
4
I–K



At the center :



In the complete structure dotted lines, numbered 1, 2, 3 and 4, show where the strained bonds are, where iodine joins on, and where hydrolysis probably first takes place. It will be noticed that in each chain one line of $C_6H_{10}O_5$ groups has the aldehydic oxygen attached toward the center of the molecule, the other line in the opposite direction. This arrangement is necessary for the interlinking and offers a possibility, as shown later, of explaining reducing dextrins. The linking throughout is the same as that of two dextrose molecules to form maltose, only the dextrose nuclei are combined in groups of two, four and six after the manner of paraldehydic condensations. The chief reason for preserving the maltose linking throughout rests upon the fact that starch hydrolyzes to maltose completely when treated with malt extract for a long time and to dextrose completely upon treatment with acid. The molecule as represented has the empirical formula, $C_6H_{10}O_5$, is non-reducing, and has three hydroxyls for every $C_6H_{10}O_5$ group. According to O'Sullivan * the rotatory power of soluble starch is $(\alpha)_d = 222° +$. Lintner and Düll's body, whose rotatory power is 196° +, doubtless contains more water than corresponds to $C_6H_{10}O_5$ in accordance with a principle to be discussed later. The formula presented agrees with Syniewski's observation that carbinol hydrolysis produces only soluble starches and carbonyl hydrolysis the dextrins and other bodies which are reducing in character.

This structure may at first sight appear to be very fanciful. I do not claim that it necessarily represents the exact arrangement of the starch molecule, but a possible graphical representation of the facts of hydrolysis of starch, etc., which have been gathered in the last hundred years. Many principles may be learned from its study which harmonize otherwise contradictory results. Let us examine the products formed by splitting the molecule proposed.

The first splittings would naturally take place at the points of strain, that is, where iodine joins on. Herzfeld † first mentions maltodextrins, which are produced by diastase at high temperatures when the hydrolytic action is weakened. Brown and Morris ‡ also found maltodextrins, one of which had the structure, $(C_{12}H_{20}O_{10})_2.C_{12}H_{22}O_{11}$. The production of maltodextrins is easily explained by the structure proposed. The first split would most

* *Jour. Chem. Soc.*, 35, 770–785.

† *Ber. Chem. Gesell.*, 12, 2120.

‡ *Ann. Chem.*, 231, 72; *Ber. Chem. Gesell.*, 24, 3, 723.

naturally produce a body composed of six $C_{12}H_{20}O_{10}$ groups, and it is more than likely that an aldehydic group would be set free and hydrolysis take place at the point of disturbance. Thus a maltodextrin would be produced of the formula, $(C_{12}H_{20}O_{10})_5.C_{12}H_{22}O_{11}$. This body would split to smaller bodies, or into halves, yielding a maltodextrin of the formula, $(C_{12}H_{20}O_{10})_2.C_{12}H_{22}O_{11}$. A maltodextrin of this type would be separated by the next two splittings of the starch molecule one after the other.

I conceive the residue from the first splitting as a possible structure for amidulin, which the experimental work of a former article* showed to be a distinct body from soluble starch, intermediate between starch and erythrodextrin. The fact that amidulin is so easily split to erythrodextrin by iodine in titration may possibly be explained by the fact that when iodine is pulled out of the amidulin iodide, there would be a tendency to hydrolyze at the point of disturbance and strain. This action might be supposed to be a characteristic of erythrodextrin also, but my experiments proved it otherwise. That amidulin is subject to such action on the part of iodine may possibly be due to the proximity of the two strains between amidulin and erythrodextrin at the splittings numbered 2 and 3. On the other hand amidulin iodide may be more easily attacked than starch iodide because of the greater solubility of the former.

The assumption that amidulin is produced by the first splitting also explains the greater ease with which potassium iodide produces a red or purplish color with amidulin and iodine, in accordance with the idea already proposed in a preceding article.† Amidulin iodide would have six iodine atoms on each chain. Four of these iodine atoms would be linked to a potassium iodide molecule; the other two would most readily link to each other, and in the presence of a fairly concentrated solution of potassium iodide would tend to attach to a potassium iodide molecule. But this would give a grouping, $KI.I_2$, which would tend to give a reddish tinge to the iodide. Even if the iodine atoms of two chains were linked together with potassium iodide there would still be two iodine atoms left for a potassium iodide molecule.

By the splitting at 3 the erythrodextrin of Lintner and Düll would be produced with a molecular weight of one third that of

* *Amer. Jour. Sci.*, May, 1902, 379.

† *Am. Chem. Jour.*, Dec., 1902, 438.

their soluble starch. It might have a slight reducing power or not, according as the two end groups joined together in similarity to the end of the original chain, or the aldehydic group remained free. Scheibler and Mittelmeier * found that a commercial erythrodextrin, with which they experimented, had an aldehydic group, but their body by analysis of a hydrazone corresponded to a smaller body than Lintner and Düll's and may have been produced by a further splitting of maltose or dextrose from a chain or two. However, Syniewski and several others have claimed reducing dextrins and such reducing dextrins can readily be formed from the structure proposed. Lintner † claims that oxidation by permanganate forms acid dextrins, an effect which Scheibler and Mittelmeier claim to have produced on their commercial dextrin by means of bromine. Such an action might rather be expected than not and, indeed, may explain the loss of iodine in hydrolyzing amidulin as shown by my experiments in a former article. ‡

The red color of erythrodextrin iodide may be explained by the presence of but two iodine atoms on each chain, and, arranged in space, the chains would naturally diverge from each other, so that the most probable grouping of iodine and potassium iodide would be $KI.I_2$, which has been already proposed to explain the red starch iodide. § The effect of an excess of potassium iodide, as in a concentrated solution, may simply intensify the red color.

The last splitting, at 4, produces Lintner and Düll's achroödextrin with a molecular weight one third that of their erythrodextrin. They describe it as having a rotation of 192° + and a reduction of 10. These properties are practically identical with those of Musculus and Grüber's || achroödextrin β, the properties of which are given as $(\alpha)_j = 190° +$ and R = 12 (R is the reduction). There is no strained bond, hence no iodide can form.

Before discussing the splitting any further there are some principles to be discussed. O'Sullivan ¶ came to the conclusion that soluble starch and the dextrins all have the same rotatory power. Brown and Heron ° came to the same conclusion, and later pre-

* *Ber. Chem. Gesell.*, 23, 2, 3060–3075.
† *Zeitschr. Angew. Chem.*, 1890, 546.
‡ *Am. Jour. Sci.*, May, 1902, 379.
§ *Am. Chem. Jour.*, Dec., 1902, 438.
|| *Bul. Soc.*, 30, 54.
¶ *Jour. Chem. Soc.*, 35, 770.
° *Ann. Chem.*, 199, 165.

sented a formula, * $(\alpha)_j = 202° - 0\,64\,R$, by which the relation between the reducing and rotatory powers of the products of starch hydrolysis is expressed, and which could hardly be true if the above conclusion were not true. The question arises as to why this is so. It would be interesting to know whether the following principle were general or not, but certainly as regards starch and the dextrins it appears that whether composed of one $C_{12}H_{20}O_{10}$ group or many linked together, the rotation does not vary. It appears also that for compounds of $C_{12}H_{20}O_{10}$ and $C_{12}H_{22}O_{11}$ the rotation depends upon the proportion of the two groups in the compound. This must be the explanation of Brown and Heron's and Brown and Morris' work. It seems, too, by Johnson's † work, that compounds of dextrose and dextrin show the same characteristic. Again, Brown and Heron obtained for granulose, after boiling, a rotation of 219.5° +; O'Sullivan found 222° + for the pure dextrins and soluble starch; pure dextrose has a rotatory power of about 53° +; pure maltose ‡ has a rotation of 138° +. Now

$$C_6H_{10}O_5 + C_6H_{12}O_6 = C_{12}H_{22}O_{11}.$$

So

$$\frac{53° + 222°}{2} = 137.5° +.$$

Hence the rule applies to maltose as a compound of dextrose and dextrin. For the sake of convenience the method of calculation may be expressed in the formula:

$$(\alpha)_d \text{ for } x(C_6H_{10}O_5).y(C_6H_{12}O_6) = \frac{x(\alpha)_d^1 + y(\alpha)_d^2}{x + y}$$

where $(\alpha)_d^2$ is the rotation of pure dextrose, 52.6° +, and $(\alpha)_d^1$ is the rotation of pure soluble starch, or dextrin, $C_6H_{10}O_5$, 222° +.

Cane sugar also answers in rotation to a compound of levulose and dextrin, thus:

$$C_6H_{10}O_5 + C_6H_{12}O_6 = C_{12}H_{22}O_{11};$$
$$\frac{(222° +) + (89.42° -)}{2} = \frac{132.58° +}{2} = 66.29° +.$$

The rotation for pure cane sugar is 66.5° +.

* *Chem. News*, 75, 42.

† *Jour. Chem. Soc.*, 73, 490.

‡ Herzfeld, *Ber. Chem. Gesell.*, 28, 440.

Likewise for compounds of maltose and dextrin the following formula applies:

$$(\alpha)_d \text{ for } x(C_{12}H_{20}O_{10}).y(C_{12}H_{22}O_{11}) = \frac{x(\alpha)_d^1 + y(\alpha)_d^3}{x+y}$$

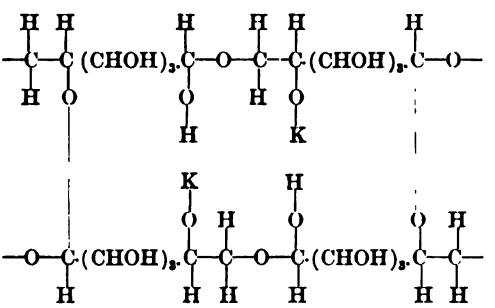
where $(\alpha)_{d^1}$ is the rotation of pure soluble starch, or dextrin, of the formula, $C_{12}H_{20}O_{10}$, and $(\alpha)_d^3$ is the rotation of pure maltose. Hence the formula becomes:

$$(\alpha)_d = \frac{x\,222^\circ + y\,138^\circ}{x+y}.$$

Maltose, dextrin, or starch according to the graphical formula cannot become aldehydic without hydrolyzing, but they may take on water, that is, hydrate, without becoming aldehydic, therefore I see nothing to prevent the production of bodies which do not follow Brown's formula, $(\alpha)_d = 202^\circ - 0.64R$, that is, the rotary power may be lowered without the body becoming reducing in power, and to this may be due in some measure the many discrepancies in the work of the various chemists. For example Brown and Heron found that for pure potassium granulose

$$(\alpha)_j = 165^\circ + \text{ to } 168^\circ +,$$

but that upon neutralization of the alkali the rotation returns to that of soluble starch. May this not be explained by the above principle, except that potassium hydroxide, instead of water, has added itself without hydrolyzing the molecule, thus:



Calling 222° the rotation of pure starch and 138° the rotation of pure maltose almost three-quarters of the starch has changed to maltose so far as hydroxyls are concerned, without the production of any reducing power. It is barely possible also that another

body which has a lower rotatory power is produced in solution by this reaction in that the hydroxyl is attached to the aldehydic carbon atom.

Again since dextrin cannot become aldehydic without hydrolyzing, if it shows reducing power it must have a rotation lower than that of soluble starch and not greater than that of the corresponding mixture of maltose and dextrin, unless some of the smaller dextrins can also be reducing without being aldehydic. For convenience in calculation the following formula may be applied:

$$(\alpha)_d = 222° - \frac{222° - 138°}{70} R \text{ or } (\alpha)_d = 222° - 1.2R.$$

I adopted the value 70 for the reducing power of maltose, since O'Sullivan found 66–67 and even then did not have a pure product as shown by the rotation of 148° +. Pure maltose should have a reducing power slightly higher than 67 or about 70. Brown and Heron gave the properties of maltose as $(\alpha)_d = 150° +$ and $R = 61$. From these data the true reduction of maltose would be 71 by the formula:

$$150° = 222° - \frac{222° - 138°}{x} 61$$

where x is the reduction of maltose. From theoretical considerations, since dextrose uses up five oxygen atoms when oxidized by Fehling's solution,* maltose should use up seven atoms which would give a reduction of seven in ten, or seventy in a hundred; that is, in the oxidation of dextrose by cupric oxide it may be considered that one oxygen atom oxidizes the aldehydic group of one end and two oxygen atoms the alcoholic group of the opposite end of dextrose to carboxyl groups. In maltose the action of a corresponding three oxygen atoms should be lacking where the two dextrose groups join together.

Let us examine the further splitting of the starch molecule, keeping in mind the above principles—that dextrin cannot become aldehydic without hydrolyzing, and that hydration may take place without hydrolysis, that is, without freeing aldehydic oxygen, although causing a lowering of the rotation.

Musculus and Grüber's† soluble starch was evidently on the

* Fehling, *Ann. Chem.*, 72, 109.

† *Bull. Soc.*, 30, 54.

borderland to erythrodextrin, since it in solution gave a reddish color with iodine. The structure I have given to amidulin, formed by a splitting at 1, might well answer for this body. With its end aldehydic groups free it should have the properties, $(\alpha)_j = 215° +$ and R = 5.8; Musculus' body had a rotation of 218° and a reduction of 6.

If we should divide the chain half way between the dotted lines 3 and 4 * we should have a body which would correspond to Musculus and Grüber's achroödextrin *a*. That body had a reduction of 12 and a rotation of 210°. On examining the molecule it is seen that, if on two of the end groups of the dextrin the aldehydic group had been set free when the outer portion of the chains had split off and consequently the same two ends had hydrolyzed, the rotation for such a body should be 208° and R = 11.6. This dextrin Musculus and Grüber describe as hydrolyzing with difficulty by diastase. It corresponds in size to approximately one-half the size of Brown and Morris' † final dextrin by diastase, or is but slightly larger than one fifth of the original molecule of soluble starch. Brown and Morris' soluble starch would then be represented by Rouvier's body, that is, a soluble starch made up of two of Lintner and Düll's molecules, the one under discussion, each chain being joined as previously shown. ‡ It is possible that all these chains in the larger bodies join in a ring in the center, or that each three join separately as represented in the structure given, or it may be that both linkings exist.

If we examine again the properties of Lintner and Düll's achroodextrin, or Musculus and Grüber's achroödextrin β, § it will be seen that their properties are explained if we assume that the ends of two chains have hydrated, giving a result of two maltose groups in six $C_6H_{10}O_5$ groups, and that the end of only one of these has a free aldehydic group also. The properties of such a body should be $(\alpha)_d = 194°$ and R = 11.8.

If we make another splitting between four and the ring we should have left the ring, which should offer more resistance to hydrolysis than the chains. The existence of such a ring was assumed partially in order to explain the resistance of a residual

* See the structure on page 159.

† *Ber. Chem. Gesell.*, 24, 3, 723.

‡ See page 160, first figure.

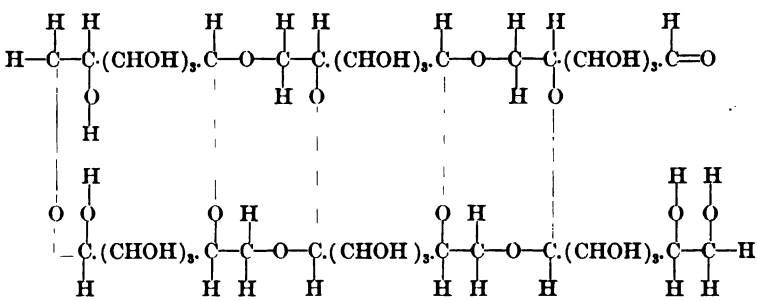
§ For the properties of these bodies see page 163, ¶ 3.

dextrin. O'Sullivan by repeated treatment with alcohol failed to dissolve out all the maltose from his dextrins; a reduction in the residue always persisted. May it not be explained by free aldehydic groups on the ends of the dextrin chains or by small quantities of a reducing residual dextrin.

A ring composed of six maltose nuclei, or a mixture of rings of three maltose nuclei, might well represent Musculus and Gruber's achroödextrin γ, the properties of which are $(\alpha)_j = 150° +$, R = 28. In this body about half of the maltose groups have hydrolyzed, freeing aldehydic groups and the remainder have hydrated only. The properties of such a body should be $(\alpha)_j = 152° +$, R = 35. A proper mixture of rings would exactly represent the reduction and rotation. This dextrin is not readily attacked by diastase.

Bondonneau's* dextrins are readily explained by hydration without the freeing of aldehydic groups, or by the closing together of the ends of the chains as portions are split off.

Herzfeld's maltodextrin, according to its properties, might be represented in some such way as this:



Herzfeld's body had a reducing power one-third that of maltose, and a rotation of about 170°. The body represented should have a reducing power of one third that of maltose and a rotation of 166°+.

In examination of mixtures of hydrolytic products it is not necessary to conclude that maltose is split off, but the aldehydic groups may be freed in maltose groups attached to the maltodextrins formed, or to the residual dextrins. Diastase acting at high temperatures and hence delayed in its action, or retarded by potassium hydroxide, sodium carbonate, or salicylic acid, would naturally split

* *Ber. d. Chem. Ges.*, 3B, 9, 6 and 69.

off simply maltodextrin groups first. Herzfeld found that his maltodextrin was produced by diastase above 65°. O'Sullivan's reaction at 69° between diastase and starch produced a reducing power in the mixture corresponding to one molecule of maltose to five of dextrin, calling the simplest dextrin $C_{12}H_{20}O_{10}$. His residual dextrin in this reaction is erythrodextrin. Brown and Heron found the ratio of maltose to dextrin at the same temperature to be one to four. If we examine the hydrolysis of the starch molecule we see that the natural splittings are at 1, 2 and 3. If half of the aldehydic groups become free and the other half remain combined, or recombine, there would be produced in the mixture a reducing power equivalent to three maltose groups out of eighteen, or one in six. The reduction and rotation values for the mixture would then equal the values which O'Sullivan found. As the hydrolysis progresses, especially at lower temperatures, the results become more complex from the splitting up of the maltodextrins produced.

Johnson's* glucodextrins by acid hydrolysis are not readily explained by the splitting off of dextrose instead of maltose, either from the residual dextrin or from bodies of a maltodextrin type, for there seems to be no way of joining two dextrose molecules together without dehydration and still keeping the aldehydic groups free. Unless the dextrose molecules are tied by dehydration the aldehydic groups must be bonded together. If the dextrose molecules are joined by dehydration they become maltose or dextrin, in power of rotation approaching that of dextrose by a sufficient amount of hydration. No possible structure presents itself for a body of the type of Johnson's smallest gluco-dextrin which has a reduction of 80 and a rotation of 81.8° +, or a ratio of one dextrin group to five dextrose groups, unless it be true that after sufficient hydration has taken place to form bodies approaching dextrose in rotation Fehling's solution gives a reduction approaching dextrose in value, as if it were a simple dextrose group. There is no reason why glucoamylins of small molecular size should not be similar in reducing character to maltose, which may itself be considered to be a glucoamylin, or glucodextrin, and which shows more reducing power than belongs to one dextrose group in two.

The criticism may be raised that in the structure proposed the

**Jour. Chem. Soc.*, 73, 490–502.

three arms may not be acted upon alike. This is very true and may be seen really to be the case in actual experience. There is only additional reason for the conflicting properties of the products of hydrolysis of starch as given by various workers. The study of the structure, as just given, amply brings out the possibilities for variation in the character of the products, even in dextrins of the same molecular size, obtained by different chemists.

It will doubtless be noticed that the ratio of iodine to the starch molecule as presented in the complete structure is not quite I: $(C_6H_{10}O_5)_4$, but I_2: $(C_6H_{10}O_5)_9$. The latter ratio is, however, as near the experimental results of analysis of starch iodide as the former, and in some cases nearer, for example:

$$(C_6H_{10}O_5)_9I_2 = 17.42 \text{ per cent.}$$

Mylius found from 17 per cent. to 19 per cent., Seyfert 18.56 per cent.

$$(C_6H_{10}O_5)_9I = 8.71 \text{ per cent.}$$

Rouvier found 8.59 per cent., 8.63 per cent., 8.75 per cent.

$$(C_6H_{10}O_5)_{27}I_2 = 5.81 \text{ per cent.}$$

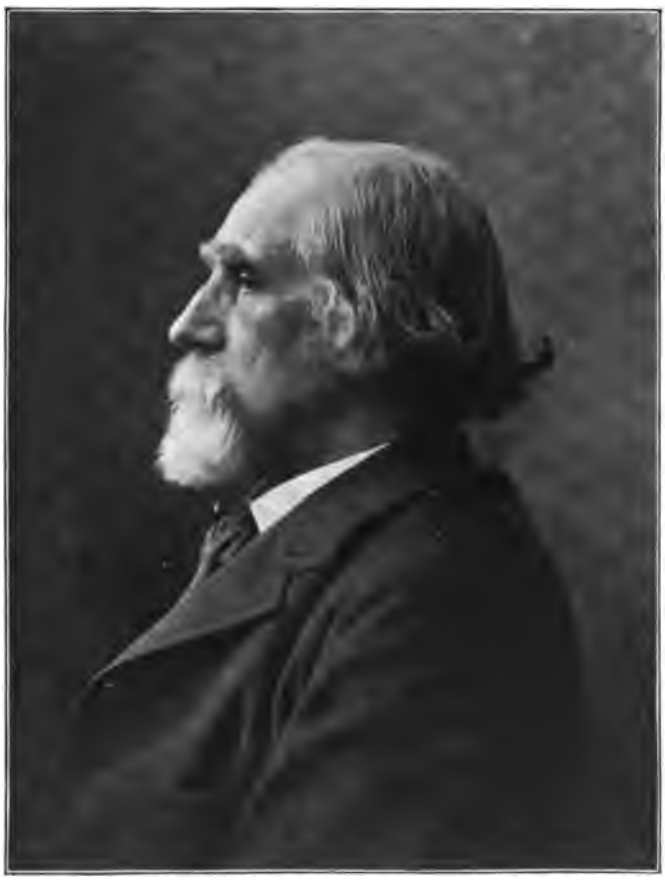
Girard found 5.25 per cent., 5.8 per cent., 5.9 per cent., 6.65 per cent.

$$(C_6H_{10}O_5)_{18}I = 4.36 \text{ per cent.}$$

One of Girard's determinations was 4.5 per cent., and my own starch iodide gave a ratio of iodine to starch of 4.38 per cent.

The proposed structure seems then to be an appropriate *graphical representation* of the facts concerning starch because it explains so many results of starch hydrolysis — molecular size, intermediate production of maltodextrins, dextrins with or without reducing power and of various rotatory powers, hydrolysis by acid, alkali, or other reagent, hydrolysis of amidulin by iodine, a possible explanation of the formation of the red and blue iodides, condensation into larger bodies and into insoluble starch cellulose, and a residue not easily attacked by diastase. It brings into harmony the results of Brown and Heron, Brown and Morris, Herzfeld, Musculus and Grüber, Bondonneau, Lintner and Düll, Scheibler and Mittelmeier, Lintner, O'Sullivan, Johnson, Mylius, Girard, and many others including a portion of Syniewski's work.

THE KENT CHEMICAL LABORATORY OF YALE UNIVERSITY.



OGDEN N. ROOD

PROFESSOR OF PHYSICS, 1864–1902

OGDEN N. ROOD.

Professor Ogden N. Rood was born at Middletown, Connecticut, on the 13th of February, 1831. He entered Yale College in 1848, and after remaining there for two years, he transferred to Princeton and was graduated from that institution in 1852. Afterward he went abroad, and spent several years of study at the University of Berlin, and afterward at Munich, becoming particularly well acquainted with Liebig in whose laboratory he worked for some time. In Munich he was married shortly before his return to this country, in 1858, and upon his return was appointed as Professor of Chemistry in the University of Troy. This institution, however, soon went out of existence, and after a year of absence from educational institutions he was installed in February of 1864 to the Chair of Physics at Columbia. It will be remembered that his predecessor had been dropped on account of his joining the Confederate Army during the Civil War. From the time of his appointment in 1864 until the time of his death on November 12, 1902, he occupied the Chair of Physics and continued to develop the department from the very insignificant beginning which existed forty years ago, into the large and well-equipped department as it is seen to-day. During all this time in spite of his doing the greater part of the departmental work himself, until very recently, he always had at least two or three investigations on hand, and scarcely a year passed without the publication of at least one article which bore the stamp of the careful experimenter and conscientious reasoner, which he always was. Even during his stay in Germany, and in the very earliest part of his career a number of articles testified to the early beginning of his research work and to his serious character. In addition to a large number of articles which appeared for the most part in the *American Journal of Science*, and also a number of public addresses, he issued in 1879 Modern Chromatics, which immediately took its position as the text-book of the artist and the physicist in regard to color and color sensation. Most of his energy was devoted to experiments in light and in electricity. His determination of the time of the electric spark, and his work upon the reflection of X-rays found their counterpart in his last investigation in developing a method

for measuring the conductivity of insulators. In the interval, however, he was always working upon color vision, and spent a number of years in perfecting the only practicable method for the comparison of intensity of lights of different colors by means of the instrument which he calls the "flicker-photomoter."

The career of Professor Rood must be of particular interest to the students and alumni of the School of Mines, since his term at Columbia is practically parallel to the development of that school, and in all of the departments of the various courses he took a keen interest and contributed, to a considerable extent, to the success by arranging for the fundamental work in his science which is so fundamental to all engineers. His method of lecturing and presentation were unique and often little appreciated by the student at the time, but in later years the student was sure to find that many of his pieces of information existed in exactly the phraseology in which they have been presented by Professor Rood. The apparent sternness of his bearing really masked the kindest of hearts, and it was only when he felt that he had been treated in an unfair or unmanly way that he really became as stern and unrelenting as he always appeared. No favor for a friend was too small or too great for his attention, and, on the other hand, he usually took a quiet satisfaction in a sly thrust at some person whom he did not rank in his favored circle. A devoted friend, and an open enemy, was one of his characteristics. Aside from his scientific interest he had for years painted in water colors, and was an artist who commanded the respect and appreciation of his fellow craftsmen. In later years he devoted himself to the study of engraved gems, particularly the early Asian and Egyptian seals and cylinders of various sorts, and he had a very fine collection of these at the time of his death.

THE GEOLOGY OF THE CERRILLOS HILLS, NEW MEXICO.*

By DOUGLAS WILSON JOHNSON.

Part II. PALÆONTOLOGY.

Introduction.

The following report on the Palæontology of the Cerrillos district is based upon a collection of fossils made by the writer during the summer of 1902. So far as I am aware, no fossils have been previously described from this locality, with the exception of a few plant remains from above the coal near Madrid, although brief references to several species of *Ostrea*, *Inoceramus*, etc., were made by the earlier explorers. The region about the Cerrillos Hills is extensively broken and faulted, and the strata are profoundly metamorphosed. As a result, much of the material in the collection is fragmentary, perfectly preserved fossils being rarely found. Fossiliferous horizons are not numerous, and as they are more often found in widely separated localities, in a region broken by many faults, details of correlation, estimates of thicknesses of beds, and other desirable data could not always be secured. In some instances, however, excellent sections were exposed, the barrenness of the country making it possible to trace the succession of the beds without difficulty. These sections are represented in diagrammatic form in Part I. of this report, where a detailed consideration of the stratigraphy will be found.

It has been no part of my plan to present herein a complete bibliography and synonymy of the fossils described. As a rule references are given to other works where such lists, together with detailed descriptions, may be found. It has been my endeavor to refer to those works most easily accessible, unless for special reasons some other reference seemed desirable.

In the preparation of this part of the report on the Geology of the Cerrillos Hills, the writer has profited continually by the advice and suggestions of Professor Amadeus W. Grabau, for whose

* The Geology of the Cerrillos Hills, New Mexico. Part I., "General Geology," and Part III., "Petrography," are in preparation, and will appear in the succeeding issues of the QUARTERLY. D. W. J.

cordial interest he desires to express his sincere gratitude. I am also under obligations to Mr. Timothy W. Stanton for the opportunity to make comparisons with certain of his types in the National Museum at Washington, as well as for valuable suggestions concerning the identity of some doubtful forms. To Mr. Frank H. Knowlton thanks are due for the identification of the fossil flora of the region, and to Dr. Bashford Dean for the identification of certain fish scales. Mr. J. L. Wells, of Cerrillos, New Mexico, kindly loaned several fossils as noted in the descriptions. To Miss Rena B. Johnson I am indebted for the care and skill bestowed upon the illustrations. Other acknowledgments will be found in the text.

Geologic Description.

The strata exposed in the Cerrillos district belong to three different periods, the oldest series being that of the Red Beds, the age of which is not known. These beds appear to be wholly barren of fossils. It can only be said that the similar beds in neighboring districts are wholly or in part of Permian or Jura-Triassic age, and, as seen in another part of this report, the evidence in the Cerrillos region indicates that they occupy a similar position here. These beds are exposed below fossiliferous Cretaceous sandstones and shales along the western border of the Cerrillos sheet, in what has been termed the Galisteo Monocline. They are of very considerable but unknown thickness.

The next period represented here is the Cretaceous. The beds consist of massive and loose yellow, gray and red sandstones and calcareous or carbonaceous shales, and occupy a large part of the southern half of the area under consideration. These beds are fairly fossiliferous in places, and a consideration of their faunal relations appears below. In a region so broken and faulted it was not possible to secure accurate estimates of the thickness of the strata, but several typical sections are given in connection with the consideration of the stratigraphy to be found elsewhere in this report.

Resting unconformably upon the strata of the preceding divisions are loose, imperfectly stratified sands of more recent age, which attain a thickness of a hundred feet or more in places. These beds, known as the Santa Fè Marls, are composed of the finer, more distant material in the great alluvial fans which spread out from adjacent mountain ranges, and so far as observed con-

tained no fossils in this region. The deposits represent at least that time interval included between the beginning of the Upper Miocene and the present epoch, and in some regions outside of the Cerrillos district attain a very great thickness. By the earlier geologists all of these beds were referred to the Tertiary. A detailed discussion concerning them will be found in Part I. of this report.

Correlation of the Cretaceous.

The following subdivisions of the western Cretaceous are generally recognized:

Laramie.	
Fox Hills Fort Pierre	Montana.
Niobrara Fort Benton	Colorado.
Dakota.	

All of the fossiliferous beds in the Cerrillos district belong to the Colorado and Montana formations, with the possible exception of the red sandstones of the Galisteo Group, in which fossil tree trunks are found, and which may be of Laramie age. If the Dakota is present, as seems most probable, it only appears at the extreme western edge of the district under consideration, in the Galisteo Monocline. At the very top of the monocline were found beds of Colorado age, below which there is a considerable thickness of yellow and gray sandstones under which are seen the Red Beds. It is probable that these yellow and gray sandstones belong to the Dakota, although I have no faunal evidence.

Cerrillos Section.

The fossils belonging to the Colorado group all come from two localities — one of which is a few rods northeast of the smelter, just north of the town of Cerrillos. Almost in contact with the intrusive mass at this point was exposed a small bed of dark, calcareous shales, striking N. 45 W. and dipping 25 N., or in toward the intrusive. This represents one of the groups of strata which are found in close proximity to the laccolith, dipping in toward it, the beds a little further removed usually dipping sharply away from the center in all directions. From these shales the following fossils were collected:

(An interrogation point before the name indicates that the identification was made with some doubt.)

Ostrea lugubris Conrad.
Inoceramus labiatus Schlotheim.
I. dimidius White.
I. fragilis H. & M.
Scaphites warreni M. & H.
Prionocylus macombi Meek.
P. wyomingensis Meek.
P. sp. nov.
Prionotropis woolgari Mantell.
Rostellites dalli var. *wellsi* var. nov.
? *R. ambigua* Stanton.
Acmæa cerrillosensis sp. nov.
Scurria? coniformis sp. nov.
Aucella strongi sp. nov.
Beryx sp. undet.

In his paper on the Colorado formation Stanton gives the following list of species which are not known to range above the Colorado, and are all sufficiently abundant and widespread to be of use in correlation:

Ostrea lugubris,
Exogyra columbella,
Gryphæa newberryi,
Avicula gastrodes,
Gervillia propleura,
Inoceramus labiatus,
I. dimidius,
I. fragilis,
I. umbonatus,
I. exogyroides,
I. deformis,
I. undabundus,
Cardium pauperculum,
Liopistha (*Psylomya*) *meeki*,
L. (*P.*) *concentrica*,
Turritella whitei,
Glauconia coalvillensis,
Pugnellus fusiformis,
Baculites gracilis,
Buchiceras swallovi,
Scaphites warreni,
Prionocyclus,
Prionotropis,
Mortoniceras.

Of the last three genera no species have been found above the Colorado formation in America.

An examination of the list of fossils reported from the shales just north of Cerrillos, as given above, shows that of the fifteen species recorded, the first nine belong in the list of forms given by Stanton as characteristic of the Colorado formation. The next two were also found in the same formation at different points in Colorado, while the last four, with the exception of the fish scales referred to *Beryx*, are new. That these shales are of Colorado age is thus established beyond question. As the exposure was small and the shales crushed and broken, no satisfactory further division could be made; any distinction such as that between the Niobrara and Fort Benton was impracticable, if indeed anything higher than Upper Fort Benton was represented.

Section Southwest of Santa Rosa Mountain.

Two miles southwest of Santa Rosa Mountain, where the main wagon road leaves the basalt-capped mesa for the valley below, there are exposed in the valley at the foot of the mesa fossiliferous shales and sandstones. The exposure is not large, but a small arroyo has removed some of the looser shales, leaving still in place the calcareous nodules in which the fossils are most abundant.

The following species were collected at this locality:

?? *Ostrea congesta* Conrad.
? *Protocardia rara* E. and S.
Astarte evansi H. and M.
Nucula subplana M. and H.
? *Solen cuneatus* Gabb.
Lingula subspatulata H. and M.
Tritonium kanabense Stanton.
Natica sp. undet.
Baculites anceps Lamarck.
? *Helicoceras pariense* White.
Beryx sp. undet.
? *Arca madridensis* sp. nov.
Cyprimeria? sulcata sp. nov.
Turritella galisteoensis sp. nov.
Admetopsis? elevata sp. nov.

Of the above fifteen species, *Astarte evansi*, so far as the writer is aware, is restricted to the upper Fort Pierre; while *Nucula subplana* has only been found in beds containing a mingling of Upper Fort Pierre and Fox Hill species. *Protocardia rara* was also found at the latter horizon. Of the new species, *Arca madridensis* is found elsewhere associated with *Inoceramus vanuxemi*, a characteristic Fort Pierre type. *Cyprimeria? sulcata* is found elsewhere associated with *Astarte evansi* and *Inoceramus vanuxemi*, in beds of Upper Fort Pierre age; while in other localities it occurs with *Inoceramus balchii*, another Upper Fort Pierre type. *Turritella galisteoensis* was not found elsewhere with any fossil whose range is already known, but occurs with *Arca madridensis* and *Cyprimeria? sulcata* in beds most probably of Fort Pierre age.

The only one of whose identity we are certain of the fifteen species that might occasion any doubt is *Tritonium kanabense* Stanton. This species occurs about 350 feet above the base of the Cretaceous section of the Upper Kanab valley in Utah, in beds which Stanton correlates with the lower part of the Colorado formation. It is very possible to conceive, however, that this form might range up into the Fort Pierre, while it is not possible to conceive that the other evidence will admit of anything but a Fort Pierre age for these beds. That the horizon is Upper Fort Pierre, is indicated by several of the fossils.

Madrid Section.

The Madrid section, a diagram of which will be found in another part of this report, was made along a nearly east and west line passing through the town of Madrid, and was about a mile and a half in length. This section shows an easterly dipping series of sandstones and shales, with several intrusive sheets of lava. At the base of this section, about a mile west of Madrid, are found beds of yellow and white sands, overlain by one of the intrusive sheets, as follows:

Intruded sheet of lava.	
Massive sandstone	30 feet
Shaly "	6 "
Massive "	6 "
Shaly "	40 "
Shaly " with concretions	30 "
(Small hiatus.)	
Loose sands with concretions,	50 "

The lower eighty feet of this section were fossiliferous, the fossils gathered being mostly weathered out, probably from the concretions. As, with the exception of one stratum, no fossils could be found in place, no detailed separation of these lower eighty feet could be made on a faunal basis. The best exposures were along a steep hillside, toward the foot of which the concretions and fossils had washed down, although a few specimens were found well toward the top. Just above the lower fifty feet of loose sands was a thin stratum made up almost entirely of *Ostrea anomioides* var. *nanus*.

The following forms were collected from this horizon:

Inoceramus simpsoni Meek.
I. cripsii var. *barabini* Morton.
I. vanuxemi M. and H.
I. sp. undet.
Placenticeras placenta (Dekay).
? Stantonoceras guadaloupæ (Roemer).
Baculites, sp. undet.
Ostrea anomioides var. *nanus* var. nov.
Endocostea brooksi sp. nov.
Arca madridensis sp. nov.
Placenticeras? intermedium sp. nov.
P.? rotundatum sp. nov.

Of the above twelve species (of which the last five are new) *Inoceramus vanuxemi*, so far as the writer is aware, does not occur above the Fort Pierre. Certainly it is a characteristic Montana form, not occurring below that formation. On the other hand,

Inoceramus simpsoni, while ranging lower, has not been found above the Fort Pierre. Of the new forms *Ostrea anomioides* var. *nanus* is found elsewhere associated with *Inoceramus vanuxemi*, while we have already seen that a form probably belonging to the species *Arca madridensis* occurs in association with *Astarte evansi* and other Fort Pierre types. *Inoceramus cripsii* var. *barabini* is a good Fort Pierre fossil, but identical or closely similar forms range much higher. The remaining forms offer no conclusive evidence. That the fauna shows a Fort Pierre age, there can be no doubt.

Half a mile east of Madrid, at the top of the Madrid section, the following succession is found, given in descending order:

Loose sand (upper part concealed)	Several feet.
Intruded lava sheet	1 "
Soft sandstone	8 "
Intruded lava sheet	3 "
Soft sandstone	10 "
More indurated sandstone	9 "
Carbonaceous shales	10 "
Sandstone	6 "
Intruded lava sheet	8–10 "
Shales	3–4 "
Coal seam	2 "

In the nine-foot band of more indurated sandstones were numerous impressions of leaves and fruits, mostly fragmentary. The following species were identified by Mr. F. H. Knowlton from a small collection made by the writer:

Ficus rhamnoides Knowlton. *Aralia?* sp.
F. uncanta Lesquereux.

Of the above species *Ficus rhamnoides* is only known from the Fox Hills beds at Point of Rocks, Wyoming. The next species has been reported from beds referred by Lesquereux to the Tertiary. But the only collections made from these beds were those made by the Hayden Survey many years ago, at which time Lesquereux referred practically everything in the Fox Hills to the Tertiary. No further evidence as to the age of these beds has been forthcoming, but the conviction has been growing in the minds of many that they are not Laramie, as now understood, but Montana.

It would seem, then, that the evidence of the plants from the coal measures at Madrid indicates a Fox Hills age for the beds at

that point. I quote the following from a letter I received from Mr. Knowlton, written on the second of February last:

"Now as to the probable age as indicated by your fossils. I am strongly of the opinion that it is Upper Montana, or, if you please, Fox Hills. Point of Rocks, whence came the *Ficus rhamnoides*, is now known to be of this age, and the other species has not been found in what we now know to be true Laramie."

Reference to Part I. of this report will show that I have there set forth in detail a discussion of the stratigraphical relations of these beds. On the basis of the stratigraphical evidence alone I would have no hesitation in referring the coal to the Fox Hills, and in fact did so refer it after my earlier work in the region. With the corroborative evidence of the plant remains, we may consider the Fox Hills age of the beds established beyond any doubt. The opinions of the earlier geologists, and the evidence upon which their opinions were based, will be found in connection with the more detailed discussion above referred to.

Achavica Arroyo Sections.

One mile northwest of Grand Central Mountain, in Achavica Arroyo, are exposed a series of sandstones and shales, dipping sharply away from the intrusive core of the main uplift, with which these beds are in contact at the eastern end of the section. At the western end the section is terminated by a fault, beyond which the beds dip toward the east, apparently away from a smaller intrusion of the lava a few rods farther west. The whole formation is profoundly metamorphosed, and the strike and dip vary considerably, the average being about N. 40 E. for the former and 50 W. for the latter.

The following beds are exposed, given in descending order:

[Fault cutting off section at western end (top).]

A. Sandstones and shaly sands	60 feet.
B. Sandstones and shaly sands	40 "

Small dyke or sheet of the intrusive.

C. Shaly sands D. Shaly sands	40 "
E. Sandstones and shaly sands	30 "
F. Mostly shales	20 "

Intrusive core of main uplift.

The above thicknesses are only approximate, exact measurements being impracticable. A few fossils were found in each of the divisions, as recorded below.

A.

Ostrea anomioides var. *nanus* var. nov.
Inoceramus vanuxemi M. and H.
? *Trigonarca obliqua* Meek.
Rostellaria? texana Conrad.

B.

? *Endocostea typica* Whitfield.
Cyprimeria? sulcata sp. nov.
? *Protocardia rara* E. and S.
Baculites anceps Lamarck.

C.

Cyprimeria? sulcata sp. nov.
? *Protocardia rara* E. and S.
Corbula nematophora var. *fitchi* var. nov.

D.

Inoceramus balchii M. and H.
I. irregularis sp. nov.
Cyprimeria? sulcata sp. nov.

E.

Inoceramus balchii M. and H.
Ammonites sp.

F.

Ammonites sp.

In several of the above divisions were found many specimens of *Inoceramus* too fragmentary for identification. The ammonites in E and F were represented by small fragments of the outer whorl, and were apparently identical with some of the Fort Pierre types found at the base of the Madrid section, such as *Placenticeras? rotundatum* or *P.? intermedium.*

Inoceramus vanuxemi and *I. balchii* are good Fort Pierre types. *Endocostea typica* is only known from the Fort Pierre. *Ostrea anomioides* var. *nanus* was found elsewhere with Fort Pierre forms, as was also *Cyprimeria? sulcata.* *? Protocardia rara* occurs in the Fort Pierre beds southwest of Santa Rosa Mountains. So far as the writer knows *Trigonarca obliqua* has not been recorded from the Fort Pierre, but it has been found not far below its base. It may range up into Fort Pierre beds, or, as shown by the interrogation point, the form found in the above locality may possibly not be identical with it. *Baculites anceps* seems to have a rather exten-

sive range. The remaining forms indicate the Fort Pierre age of the beds.

Some distance farther south in the Arroyo and one mile west of Grand Central Mountain, are found several hundred feet of shales rich in concretions, which vary in dip from 20–25° E. to vertical. These shales are profoundly altered, being in contact with the intrusive mass at the east. The following fossils were gathered at the western end of the section, where they are usually found in the concretions.

?? Ostrea congesta Conrad. *Cyprimeria ? sulcata* sp. nov.
Arca madridensis sp. nov. *Turritella galisteoensis* sp. nov.

A number of other forms were secured, but were so fragmentary and altered that not even provisional identifications could be made. As the above three species (concerning whose identity we are sure) are all of them new, and constitute the only evidence we have as to the age of the beds, it is evidently impossible to give any definite opinion regarding this point. The fact that wherever else these species have been found in the region they have been associated with Fort Pierre types, makes it appear probable that these beds belong to the Fort Pierre group. Such evidence alone, however, cannot be considered conclusive.

Section Northwest of Waldo.

Near the wagon road, three miles northwest of Waldo, a few fossils were collected which had weathered out of the shales over which the road passes. There is no definite exposure of these shales at this point, and the fossils were found lying on the surface, usually where large concretions had broken apart but resisted the weathering which removed the lighter shales. It will be understood, then, that no definite horizon for the occurrence of these forms can be given. The following species were represented:

Inoceramus labiatus Schlotheim. *Placenticeras placenta* Dekay.
? Astarte evansi H. and M. *P.* sp. undet.
Stantonoceras pseudocostatum sp. nov. *Baculites anceps* Lamarck.

Inoceramus labiatus is regarded as characteristic of the Colorado formation. *Astarte evansi*, on the other hand, is characteristic of the Montana. A single impression was referred to that species with an interrogation point, although it seemed to the writer that the reference was most probably correct. The form of *Placenti-*

ceras placenta found here is the large variety which seems closely similar to the New Jersey forms. As said before, the range of *Baculites anceps* seems rather extensive. The ancestral types of *Stantonoceras pseudocostatum* are found in the Fort Pierre. It is apparent then that nothing definite can be said with regard to the age of these beds, especially when there is the possibility for a mingling of faunas from widely different horizons such as exists at the locality in question. No assumptions can be based upon material collected in such a manner as these forms necessarily were, beyond that which the fossils themselves indicate—that the collection probably represents a mingling of faunas weathered out from beds of different ages.

Galisteo Monocline Section.

A mile or more west of the above locality, just south of the wagon road, are exposed easterly dipping shales which form the most eastern exposure of the Galisteo Monocline. About one hundred feet of these shales are shown between interbedded sheets of lava, and from them the following fossils were collected:

Ostrea lugubris Conrad. *Inoceramus* sp. undet.
? *Astarte evansi* H. and M.

Since the species *Ostrea lugubris* was quite abundant, and is regarded as characteristic of the Colorado formation, it is probably safe to regard these shales as of Colorado age. The specimens doubtfully referred to *Astarte evansi* may possibly be a distinct species.

Section Near San Marcos Reservoir.

About one half mile west of the reservoir in San Marcos Arroyo, and in a branch of that arroyo, was found a large mass of shales and sandstones apparently surrounded by the eruptive. These beds were naturally much altered, but the following forms could be identified:

Inoceramus vanuxemi M. and H. *Astarte evansi* H. and M.
? *Tritonium kanabense* Stanton.
Cyprimeria? *sulcata* sp.nov. *Baculites* sp. undet.

The occurrence of the first three forms leaves little or no doubt but that the beds here represented are of Fort Pierre age. As seen in a preceding section, *Tritonium kanabense* occurs in beds containing an undoubted Fort Pierre fauna.

Grand Central Mountain Section.

On the western slope of Grand Central Mountain, and well toward the summit, there was found an inclusion of shales an acre or less in extent, completely surrounded by the intrusive. These shales were fairly rich in specimens of *Inoceramus*, none of which it was possible to identify, so fragmentary and altered were they.

Section East of Cerrillos.

Beginning about a mile east of Cerrillos, and extending a mile or more further eastward, is exposed a great thickness of easterly dipping sandstones. The lower portion of these beds is composed of yellow and gray sandstones, overlying the coal measures and apparently conformable with them. A careful search revealed no fossils in any part of this series. The upper portion of these beds consists of deep red sandstones, which so closely resemble the sandstones of the "Red Beds" proper that considerable discussion as to their age has resulted. There is no evidence of any fault which might bring the Red Beds up above the Cretaceous at this point, however, and the beds in question seem to lie conformably upon the undoubted Cretaceous below. In one place in this group, which Hayden has called the Galisteo Group, fossil tree trunks are abundant, and an examination of thin sections of one of these by Mr. Knowlton proved it to be a highly organized dicotyledon, wholly unlike anything known from the Red Beds, but of evident Upper Cretaceous (or later) affinities. The tree was regarded as very probably belonging to the genus *Quercus*.

It seems most probable, then, that the Galisteo Group is of Upper Fox Hills or Laramie age. A full discussion of the stratigraphic relations will be found in Part I. of this report.

DESCRIPTION OF SPECIES.

MOLLUSCOIDEA.

BRACHIOPODA.

Lingulidæ.

Genus LINGULA Bruguière.

LINGULA SUBSPATULATA H. and M. (Pl. I., Fig. 11, *a*, *b*.)

For description and synonymy see Rep. Geog. and Geol. Expl. west of 100th Mer., Vol. IV., Pt. I., p. 169.

Of this species I have one example from the Cerrillos region, and several from a locality a few miles southeast of the area properly under discussion. The specimen from the Cerrillos district was found in the shales southwest of Santa Rosa Mountain, the shell itself being preserved, except the upper portion about the beak. Its perfect agreement with the description of the type leaves no doubt as to its identity.

Locality and Position.—Near wagon-road just south of basalt-capped mesa, two miles southwest of Santa Rosa Mountain, in shales of Fort Pierre age. The more perfect specimens, one of which is also figured, were collected from the clay beneath the coal at the most northern of the coal mines east of the Ortiz Mountains owned by the Santa Fé Gold and Copper Company. (Col. Univ. Coll. Pal., No. 14960, *a*, *b*.)

MOLLUSCA.

PELECYPODA.

Ostreidæ.

Genus OSTREA Linnæus.

OSTREA ANOMIOIDES var. NANUS var. nov. (Pl. I., Fig. 10, *a*, *b*, *c*, *d*.)

For description and synonymy of *Ostrea anomioides* Meek, see Bull. U. S. G. S., No. 106, p. 55.

Shell small, thin, depressed plano-convex, ovate or circular in outline; usually a little straightened along cardinal margin; no

scar of attachment visible. Lower valve rather shallow, beak a little elevated and scarcely projecting beyond cardinal margin; muscular scar subreniform, quite distinctly impressed, subcentral; upper valve nearly flat, muscular scar indistinct. Cartilage pits obscure. Surface of both valves ornamented with concentric wrinkles, most prominent on the upper valve; fine radiating striæ seen near anterior margin of a few lower valves.

Greatest diameter of average specimen, 13 mm.; breadth, 10–13 mm.; convexity, 3 mm.

This delicate shell occurs in great abundance at one horizon exposed a mile west of Madrid, making up the greater part of a stratum several inches in thickness. The specimens seem to compare fairly closely with Meek's description of *O. anomioides*, except that they are decidedly smaller, probably representing a dwarfed variety of that species. In his description Mr. Meek does not refer to the fine radiating striæ, but the figure of the lower valve of his type specimen given by White in the Twelfth Annual Report of the U. S. Geol. and Geog. Surv. of the Territories, shows that such striæ existed.

Locality and Position.—One mile west of Madrid in sandstones of Fort Pierre age. Also in Achavica Arroyo, one mile northwest of Grand Central Mountain, in strata of same age. (Col. Univ. Coll. Pal., No. 14961.)

? OSTREA CONGESTA Conrad.

For description and synonymy see Bull. U. S. G. S., No. 106, p. 55.

In the beds southwest of Santa Rosa Mountain there is one thin stratum which is made up almost entirely of a species of *Ostrea*. The beds are so metamorphosed, however, that it was impossible to secure any specimens capable of being positively identified. It is quite evident that the forms were extremely variable, but they bear a general resemblance to Conrad's species.

Locality and Position.—Near wagon road just south of basalt-capped mesa, two miles southwest of Santa Rosa Mountain, in strata of Fort Pierre age. Also found in the beds of same (?) age in Achavica Arroyo, one mile west of Grand Central Mountain. (Col. Univ. Coll. Pal., No. 14962.)

OSTREA LUGUBRIS Conrad.

For description and synonymy see Bull. U. S. G. S., No. 106, p. 58.

This extremely variable species is well represented in the Cerrillos region. Our specimens show nearly every variety of form

we have seen figured, and vary in size from those measuring 11 mm. from beak to base to others twice as large. The outline varies from almost circular to subovate or subtriangular. The radiating plications seem to be more compressed and elevated in some of our specimens that in any we have seen figured. Reniform muscular scars are deeply impressed in some individuals, less prominent in others.

Locality and Position.—A few of our specimens came from the Fort Benton shales just north of the town of Cerrillos, but the greater number were secured at the top of the Galisteo Monocline south of the road, several miles west of Cerrillos, in strata of same age. (Col. Univ. Coll. Pal., No. 14963.)

Aviculidæ.

Genus INOCERAMUS Sowerby.

INOCERAMUS FRAGILIS H. and M. (Pl. II., Fig. 17.)

For description and synonymy see Bull. U. S. G. S., No. 106, p. 76.

One poorly preserved internal mold of a right valve from the metamorphosed shales just north of the town of Cerrillos, is referred to this species. The shell is higher than long, with anterior side vertically truncate; the beak is pointed, curves inward and forward, and rises but little above the hinge-line. Obscure traces of concentric undulations still remain.

Locality and Position.—Just north of Cerrillos, in shales of Fort Benton age. (Col. Univ. Coll. Pal., No. 14964.)

INOCERAMUS LABIATUS Schlotheim.

For description and synonymy see Bull. U. S. G. S., No. 106, p. 77.

In the collection from the shales north of Cerrillos there is one specimen, a part of a right valve, which so closely resembles the specimen figured on Plate XIV. of Stanton's paper that it might be considered the original of his Fig. 2; while a left valve from northwest of Waldo, might be the complement of his Fig. 4, Pl. X. Associated with the former were a large number of specimens which might be the elongated forms of the latter type, but which are too poorly preserved to be determined with certainty.

It seems to the writer that these two forms are specifically distinct, but until they are studied from the standpoint of their

phylogeny the opinion of those most familiar with the forms should be deferred to.

Locality and Position.—North of the town of Cerrillos, in shales of Fort Benton age. Also near wagon road, three miles northwest of Waldo, associated with *Baculites anceps* and *Stantonoceras pseudocostatum.* (Col. Univ. Coll. Pal., No. 14965.)

INOCERAMUS DIMIDIUS White. (Pl. II., Fig. 18.)

For description and synonymy see Bull. U. S. G. S., No. 106, p. 78.

Of this small species I have three specimens, one right and two left valves. They agree fairly well with the revised description quoted in Stanton's paper, but as a few additional points are noted the following is also given:

Shell very small, gibbous, obliquely subovate in outline; hinge-line short and straight; anterior margin subtruncate above, sloping abruptly backward below and rounding gradually into basal margin; posterior margin rounding from hinge-line gradually and regularly into basal margin, the latter being regularly convex; beaks small, pointed, incurved, inclined forward, situated close to anterior margin, and projecting but slightly above cardinal margin. Surface ornamented with regular, subangular, concentric ridges, separated by moderately wide concave interspaces; also by concentric lines between the ridges, which may not be preserved.

The two most perfect valves in the collection are a little smaller than those figured in Stanton's paper, and do not preserve the finer lines above referred to. The third valve is larger, and retains the more delicate markings, but is badly broken. It is to be noted that the rather prominent angle occurring about one third of the way down the anterior margin of our specimen, is represented in Fig. 5 of the above bulletin as occurring on the posterior margin; while the more evenly rounded outline is that of the posterior margin in our form, but that of the anterior margin in the former.

Locality and Position.—Just north of the town of Cerrillos in shales of Fort Benton age. (Col. Univ. Coll. Pal., No. 14966.)

INOCERAMUS SIMPSONI Meek.

For description and synonymy see Bull. U. S. G. S., No. 106, p. 79.

Of this species I have only the portion of a left valve, but the large size, great length, subtruncate posterior margin, and long, straight hinge-line leave no doubt as to its identity. The concen-

tric undulations are moderately distinct, regular, and separated by moderately wide interspaces. When complete, the height of the shell must have been something over four inches.

Locality and Position.—One mile west of Madrid, in loose sands of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14967.)

INOCERAMUS VANUXEMI M. and H. (Pl. III., Fig. 19.)

For description and synonymy see Rep. on Geol. of Black Hills of Dakota, p. 396.

To this species a number of fragments are referred, one of which is figured on Plate III. This specimen is from Achavica Arroyo, a mile northwest of Grand Central Mountain, and preserves traces of the finer lines between the concentric ridges, some eight or nine such lines occurring between the crests of any two ridges toward the outer margin of shell.

Other examples from same locality show the character of the prominent subangular ridges, and the broader concave interspaces.

Locality and Position.—Besides the one figured, several other specimens from the same locality are referred to this species. These occur in hard, metamorphosed sandstones of Fort Pierre age. At the base of the Madrid section were found two specimens, in loose sands of the same age, while in the inclusion of sands and shales caught up in lava half a mile west of the reservoir in San Marcos Arroyo there was found one fragment referred doubtfully to this species. (Col. Univ. Coll. Pal., No. 14968.)

INOCERAMUS BALCHII M. and H. (Pl. II., Fig. 16.)

For description and synonymy see Rep. U. S. G. S. Terr., Vol. IX., p. 56.

Of this species I have but two examples. They agree in general with Meek's description given in above reference, but seem to be a somewhat less accelerated type. The concentric undulations are more pronounced, and extend further out toward margin of shell.

To Meek's description the following may be added: In addition to the concentric undulations, the surface is ornamented with fine concentric lines, especially well shown in the concave interspaces between the ridges. Also, along hinge-lines at least, traces of faint radiating lines.

Locality and Position.—Achavica Arroyo one mile northwest of Grand Central Mountain, in strata of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14969.)

INOCERAMUS CRIPSII var. BARABINI Morton. (Pl. V., Fig. 22.)

For description and synonymy see Rep. U. S. G. S. Terr., Vol. IX., p. 49.

The right valve figured on Plate V. is referred to this species as figured and described by Meek in the above cited reference. It is the only example of this species occurring in the collection, and was found in the loose sands at the base of the Madrid section, associated with such forms as *I. simpsoni*, *Endocostea brooksi*, *Ostrea anomioides* var. *nanus*, etc. The shell is about 45 mm. in height, and shows fine concentric lines of growth between the somewhat worn, regular undulations.

Locality and Position. — One mile west of Madrid in loose sands of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14970.)

INOCERAMUS IRREGULARIS sp. nov. (Pl. IV., Fig. 21, *a*, *b*.)

Shell rather large, subovate, very gibbous, the greatest convexity being in the antero-dorsal region; length (apparently) about one and one half times as great as height; anterior end narrower than posterior; ventral margin rounding obliquely upward toward anterior margin; posterior margin unknown; hinge-line long and straight; beak (absent) situated well toward anterior end. Surface ornamented with prominent, extremely irregular extravagantly developed concentric ridges, separated by rather narrow interspaces; finer markings not shown. Height 85 mm.; convexity left valve, 25 mm.; exact length not known, but not greater than 130 mm.

Although this species is only known from the internal mold of a portion of a left valve, its specific characters are so pronounced as to render future identification of similar types practicable. Even in its fragmentary condition it is readily distinguished from *I. simpsoni* or *I. oblongus*, which the portion still remaining most resembles, by the absence of subtruncate posterior margin (as indicated by the concentric ridges), and also in the case of *I. simpsoni*, by the evident greater width as compared with length.

Locality and Position. — Achavica Arroyo, one mile northwest of Grand Central Mountain, in sandstones of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14971.)

INOCERAMUS sp. nov. ? (Pl. III., Figs. 20, *a*, *b*.)

There are in the collection internal molds of both valves of an *Inoceramus*, still united, and with a small portion of the shell still

adhering along the hinge-line. As the outline of the shell is not preserved in either case, I have thought best not to establish a new species, although the specimen appears to differ from anything I have seen described. The following incomplete description is given:

Shell of medium size, only moderately convex, umbones broad and flat; outline probably subovate, length greater than height; hinge-line long and straight; beaks incurved, projecting but slightly beyond cardinal margin. Surface ornamented with more or less regular, small, low concentric undulations. Convexity of right valve, 7 mm.

Locality and Position. — One mile west of Madrid, in loose sands of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14972.)

INOCERAMUS sp. undet.

Inoceramus is probably the most abundant species found in this region. But since the strata are usually greatly metamorphosed, the fossils contained in them are generally so crushed or altered that few good individuals are to be found. Hence it is that although a large number of specimens of *Inoceramus* were collected, comparatively few admitted of identification, while many remain whose specific character it is impossible to determine.

On the western slope of Grand Central Mountain, and well up the mountain side, there was found an inclusion of shales, caught up and completely surrounded by the eruptive. These shales were rich in several species of *Inoceramus*, but were so profoundly altered that not one of the specimens would admit of even reasonably certain identification. As no other fossils were found, no clue as to the definite age of these shales could be obtained.

In addition to these fragmentary specimens there were found in the shales just north of the town of Cerrillos a number of poorly preserved forms of very small size which might be the young of *Inoceramus*.

Genus ENDOCOSTEA Whitfield.

? ENDOCOSTEA TYPICA Whitfield.

For description and synonymy see Rep. Geol. Black Hills of Dakota, p. 403.

Two impressions of *Endocostea* in the collection are referred to Whitfield's species with some doubt, as only a small portion of the impression remains in each case. Judging from the character of the concentric undulations, and the distinct sulcus, however, the reference is probably correct.

Locality and Position.— Achavica Arroyo, one mile northwest of Grand Central Mountain, in sandstone of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14973.)

ENDOCOSTEA BROOKSI, sp. nov. (Pl. V., Fig. 23, *a*, *b*.)

There are a few specimens of *Endocostea* in the collection which differ markedly from any species hitherto described. Unfortunately in none of the cases is the form entirely preserved, although the specific characters are well enough shown, it is believed, to enable the identification of similar types without difficulty.

The entire shell was only moderately large, irregularly suborbicular in outline, gibbous, the greatest convexity being midway between beak and base; length probably a little greater than height; anterior margin making an angle of about 90 degrees with the hinge-line, and rounding gradually backward toward base; hinge-line long and straight; remainder of marginal outline not preserved. Beaks depressed, slightly incurved, projecting a little above hinge-line, and placed near anterior margin.

Surface ornamented with concentric folds or ridges, which may be considered in two classes; the first ten or twelve being small, rather low, and close together, and extending to where the shell attains its maximum convexity; the last four or five being large, extravagantly developed, situated far apart, and extending from the line of maximum convexity rather abruptly downward to the base of the shell. When seen in profile the shell presents two distinct slopes, making a rather marked angle with each other, the one ornamented with the smaller, closely arranged ridges, the other with the large, extravagantly developed series. These two series do not grade one into the other, but the change is as sudden and complete as that of the angle in slope. In addition to these folds or ridges there are fine concentric lines of growth.

Oblique sulcus strongly marked, narrow and pointed toward the beak, but widening and deepening posteriorly; concentric ridges distinctly crossing this sulcus.

The character of ornamentation and the relation of the same to the prominent angle made by the two different slopes on the shell will readily distinguish this species, which is named after Mr. Herbert O. Brooks, who accompanied the writer during some of his earlier work in this region.

Locality aad Position.—One mile west of the town of Madrid, in loose sands of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14974)

Genus AUCELLA Keyserling.

AUCELLA STRONGI, sp. nov. (Pl. I., Fig. 1, *a*, *b*, *c*, *d*, *e*.)

Shell small, inequivalve, convex, high and narrow. Left valve with beak prominent and very strongly incurved, placed along anterior margin, and directed so distinctly forward as to give it a spiral form; posterior ear well extended and strongly marked; hinge-line long and straight; a prominent, subtriangular, concave area is bounded on one side by the hinge-line, on another by the posterior ear, with which it makes a distinct angle, while on the third side the area is truncated by the anterior surface of the shell; anterior portion (at least) of area marked by transverse striæ. Right valve (only one poor example seen) apparently less convex; beak very much less prominent, small and pointed; byssal groove and notch not shown. Surface of both valves marked by low, ill-defined concentric undulations, and fine, obscure radiating striæ, the latter sometimes being obsolete.

Extreme length of average specimen, 24 mm.; extreme breadth, 18 mm.; convexity, 10–12 mm.

This species may be readily distinguished from the forms described by Stanton and others from the Pacific coast by its more prominent posterior ear and well developed adjacent subtriangular area, its more incurved beak, and the great convexity of the shell. The area is even more prominent than that shown in Fig. 9, Pl. III., of Lahusen's monograph "Ueber die Russischen Aucellen,"* while the transverse striæ were quite noticeable on one specimen, and are possibly analogous to the radiating striæ on the rest of the shell. The species is named after Dr. O. S. Strong, who accompanied the writer in the field.

Locality and Position. — Just north of the town of Cerrillos, in shales of Fort Benton age. (Col. Univ. Coll. Pal., No. 14975.)

* "Mém. du Comité geologique," Vol. VIII., No. 1, St. Petersburg, 1888.

Arcidæ.

Genus ARCA Lamarck.

ARCA MADRIDENSIS sp. nov. (Pl. I., Fig. 2.)

Shell small, convex, longer than wide; beaks quite prominent, incurved, inclined forward, situated anterior to the middle; cardinal margin almost as long as shell; anterior margin rounded, sloping obliquely back toward ventral margin; posterior margin subtruncate; ventral margin rounded in front, rather straight behind, approximately parallel with hinge; area long and narrow.

Surface ornamented with from 20 to 24 prominent, simple, radiating costæ, increasing in width toward margin, and making the latter beautifully crenulate. Dentition very obscure, apparently that of *Arca*.

Length of type specimen 10 mm.; height 7 mm.; convexity of single valve 2.5 mm.

Of this species I have but two left valves, and one badly distorted right valve, the latter of doubtful identity. The type specimen is well preserved, except that the dentition is obscured by the matrix, from which it seems impossible to separate the shell with safety.

Locality and Position. — The type came from one mile west of Madrid, in sandstone of Fort Pierre age. The other left valve came from the Fort Pierre (?) shales in Achavica Arroyo, one mile west of Grand Central Mountain, and the right valve from near wagon road just south of basalt-capped mesa two miles southwest of Santa Rosa Mountain, in shales of the same age. (Col. Univ. Coll. Pal., No. 14976.)

Genus TRIGONARCA Conrad.

? TRIGONARCA OBLIQUA Meek.

For description and synonymy see Bull. U. S. G. S., No. 106, p. 92.

There are two internal molds of *Trigonarca* in the collection which I believe belong to this species; they have been so crushed as to render absolute identification impossible. The imprints of the concentric lines of growth have been impressed on the molds, and their non-conformity along several fracture lines shows that the specimens were subjected to considerable distortion. They agree

so closely with the original description in most points, however, that the reference is probably correct.

Locality and Position. — Achavica Arroyo, one mile northwest of Grand Central Mountain in sandstone of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14977.)

Nuculidæ.

Genus NUCULA Lamarck.

NUCULA SUBPLANA M. and H.

For description and synonymy see Rep. U. S. G. S. Terr., Vol. IX., p. 99.

Of this species I have but one specimen, retaining the shell with surface markings, in part. As presumed by Meek, who had seen only internal molds, the ornamentation consists of fine concentric striæ. The shell itself is quite thin. The dentition and muscular impressions are not shown, but in other respects the shell agrees closely with the original description.

Locality and Position.— Near wagon road just south of basalt-capped mesa, two miles southwest of Santa Rosa Mountain, in shales of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14978.)

Crassatellidæ.

Genus ASTARTE Sowerby.

ASTARTE EVANSI (H. and M.) Whitfield. (Pl. V., Fig. 24, *a*, *b*, *c*.)

For description and synonymy see Rep. Geol. Black Hills of Dakota, p. 413.

This species is quite abundant in the Cerrillos region, especially in the Fort Pierre shales southwest of Santa Rosa Mountain. The shells agree closely with the description given by Whitfield. The strong muscular imprints and crenulate margins of the valves are well shown. The surface ornamentation is rather variable, the concentric lines being quite simple in cases, gathered into irregular wrinkles in others, or even developing into fairly regular low concentric undulations separated by narrower interspaces. Some internal molds show traces of the obscure radiating lines mentioned by Meek.

Associated with the typical forms of *A. evansi* found in the inclusion of shales in the lava west of the reservoir, were a number

of internal molds of smaller forms which are referred to the young of this species. A wax impression of the hinge of a moderately large example shows the characteristic dentition of *Astarte*.

Locality and Position.—Near wagon road, just south of basalt-capped mesa, two miles southwest of Santa Rosa Mountain, in shales of Fort Pierre age. Also from inclusion of shales in lava in branch of San Marcos Arroyo, half a mile west of reservoir. An impression from the sandstones along wagon road three miles northwest of Waldo is referred to this species with some doubt. One specimen from the top of the Galisteo Monocline, south of wagon road, may belong to this species. (Col. Univ. Coll. Pal., No. 14979.)

Cardiidæ.

Genus PROTOCARDIA Beyrich.

? PROTOCARDIA RARA E. and S.

For description and synonymy see Rep. U. S. G. S. Terr., Vol. IX., p. 176.

A few poorly preserved specimens are doubtfully referred to this species. They differ from the typical *P. rara* in having the radiating costæ continuing farther toward the beak. The umbonal region is quite gibbous, however, and in other respects they would seem to agree fairly well with the description given by Evans and Shumard. The specimens are too fragmentary to speak with certainty.

Locality and Position. — Achavica Arroyo, one mile northwest of Grand Central Mountain in sandstone of Fort Pierre age. Also from near wagon road just south of basalt-capped mesa, two miles southwest of Santa Rosa Mountain, in shales of same age. (Col. Univ. Coll. Pal., No. 14980.)

Veneridæ.

Genus CYPRIMERIA Conrad.

CYPRIMERIA? SULCATA sp. nov. (Pl. VI., Fig. 25, *a*, *b*, *c*, *d*.)

Shell moderately thick, of medium size, somewhat convex, subcircular in outline; beaks small, situated a little anterior to the middle; cardinal margin sloping with nearly equal convexity in both directions from beaks; anterior end regularly rounded; pos-

terior end subtruncate; ventral margin regularly curved; hinge not well preserved, but shows what appears to be the dentition of *Cyprimeria;* muscular scars ovate, not often shown; pallial sinus (only seen in one specimen) shallow. Surface ornamented with fine concentric lines.

On internal molds the posterior portion of each valve is marked by a broad, shallow sulcus, which originates on the upper portion of the shell posterior to the beaks, curves downward toward the ventral margin, is roughly parallel to the posterior margin, and becomes more distinct as it progresses.

Length of average specimen 50 mm.; height 43 mm.; convexity (both valves) 10 mm.

This species is very abundant, but since the matrix is usually a dense hard sandstone considerably metamorphosed, or profoundly metamorphosed shales, no perfect specimens were secured. The rather prominent sulcus seems to the writer to be a character of generic value, but he does not feel justified in establishing a genus on the basis of such fragmentary material. The figure of *C. discus* Math. which appears in Zittel's "Grundzüge der Palaeontologie," p. 298 (Eastman's Zittel, p. 415) shows what appears to be a depression of the nature found in the specimens at hand. I have not been able to secure the description of this species, so cannot make the desired comparison.

Locality and Position.—Achavica Arroyo, one mile northwest of Grand Central Mountain, in sandstones and shales of Fort Pierre age. Two specimens from further south in the Arroyo, one mile due west of the mountains, in shales of same (?) age, are doubtfully referred to this species. Near the wagon road just south of basalt-capped mesa, two miles southwest of Santa Rosa Mountain, a number of specimens with portions of the shell still adhering were secured from shales of same age. A few specimens from the inclusion of shales in lava half a mile west of the Reservoir in San Marcos Arroyo are of doubtful identity. (Col. Univ. Coll. Pal., No. 14981.)

Solenidæ.

Genus SOLEN Linn.

? SOLEN CUNEATUS Gabb. (Pl. I., Fig. 4.)

Solen (*Hypogella*) *cuneatus* Gabb, 1869, Geol. Surv. Cal. Palæont, Vol. II., p. 175, pl. 29, fig. 61.

To this species I refer, with some uncertainty, a poorly pre-

served right valve. The shell was evidently narrowed anteriorly, as shown by the lines of growth, which gradually approach the straight hinge margin as they pass forward. The posterior end is broadly convex, and the shell agrees closely in size with Gabb's species.

Locality and Position.—Near wagon road just south of basalt-capped mesa, two miles southwest of Santa Rosa Mountain, in shales of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14982.)

Myidæ.

Genus CORBULA Bruguière.

CORBULA NEMATOPHORA var. FITCHI var. nov. (Pl. I., Fig. 3.)

Cf. *Corbula nematophora* Meek, Eleventh Annual Rep. U. S. Geol. and Geog. Sur. Terr., p. 290, pl. 3.

Shell small, subtriangular, convex; beaks fairly prominent, a little anterior to the middle; cardinal margin sloping almost equally from beaks in both directions; anterior end regularly rounded; posterior end truncated above, rounding rather sharply into ventral margin below; ventral margin nearly straight posteriorly, rounding regularly into anterior margin, subangular umbonal ridge extending from beaks to postero-ventral margin. Surface ornamented with distinct concentric ridges, quite prominent, and separated by wider interspaces.

Length of average specimen, 14 mm.; height, 11 mm.; convexity of single valve, 3–4 mm.

This form is fairly abundant, and seems to preserves its features without great variation. I cannot doubt its close relation to *C nematophora*, but it seems to me that our specimens are distinct from either of the two widely different forms figured by White. The distinctly subtruncate posterior end and straight posterior portion of ventral margin will serve to distinguish our form. It may be distinguished from *C. filosa* Stanton by the above features and the prominent concentric ridges. The variety is named after Mr. Hereford G. Fitch, who accompanied the writer during some of his earlier work in this region.

Locality and Position.— Achavica Arroyo, one mile northwest of Grand Central Mountain, in sandstone of Fort Pierre age. (Col. Univ. Coll. Pal, No. 14983.)

GASTROPODA.

Patellidæ.

Genus ACMÆA Eschscholtz.

ACMÆA CERRILLOSENSIS sp. nov. (Pl. I., Fig. 9, *a*, *b*.)

Shell exceedingly small for this genus, very thin, depressed, conical, apical angle large; apex but slightly eccentric, rather obtusely pointed; in some specimens showing a slight tendency toward forward obliquity; aperture circular. Surface ornamented by exceedingly fine concentric striæ, while near the outer edge of some specimens there seems to be a slight tendency toward the development of minute concentric ridges. Uncertain evidence of radiating striæ occasionally seen.

Diameter of average specimen, 1.5 mm. Diameter of largest specimen seen, 2.5 mm.

This tiny shell is exceedingly abundant in the black calcareous shales just north of the town of Cerrillos, and may be readily distinguished from other species of *Acmæa* by its minute size. The extreme abundance of the shell without the presence of larger individuals, together with the indications of mature growth furnished by the development of the slight concentric ridges, will not admit of its being considered the young of some larger species. On none of the specimens could a muscular scar be made out. The species is referred to *Acmæa* mainly on the basis of its external characters.

Locality and Position.— North of the town of Cerrillos, in shales of Fort Benton age. (Col. Univ. Coll. Pal., No. 14984.)

Genus SCURRIA Gray.

SCURRIA? CONIFORMIS sp. nov. (Pl. I., Fig. 8, *a*, *b*.)

Shell small, high conical, beak nearly central, apparently directed a little forward; aperture nearly or quite circular. Sides of shell slightly concave, the apical angle being about 65 degrees. Surface ornamented by fine concentric striæ.

Diameter of type specimen, 6 mm.; height, about 3.5 mm.

I have but three specimens of this shell, the immediate apex in each case being broken off. Enough remains, however, to indicate a more or less distinct inclination of the apex to one side. Regarding the generic relationships of this species I am in consid-

erable doubt. Not having the original description of the genus *Scurria* at hand, I have had to rely on brief quoted descriptions, and those I have seen all describe the aperture as oval, or rounded oval. As noted above, in the species described the aperture is nearly or quite rounded. At the same time the very high conical shape and small apical angle distinguish it from other patelliform shells.

Locality and Position.— North of the town of Cerrillos, in shales of Fort Benton age. (Col. Univ. Coll. Pal., No. 14985.)

Naticidæ.

Genus NATICA Lamarck.

NATICA sp. undet.

Of this genus I have but one specimen, from the Fort Pierre shales southwest of Santa Rosa Mountain. Although it does not seem to agree with any described form, it is too poorly preserved to admit of specific identification or description. (Col. Univ. Coll. Pal., No. 14986.)

Turritellidæ.

Genus TURRITELLA Lamarck.

TURRITELLA GALISTEOENSIS sp. nov. (Pl. I., Fig. 5.)

Shell rather small, elongate, slender, sides straight; volutions apparently not more then nine or ten when full grown; sides of volutions slightly convex; suture deeply impressed. Surface marked by four to five fine, compressed, elevated spirals, separated by wide interspaces; the upper two spirals on each whorl usually smaller and situated closer together.

All of the specimens at hand are more or less broken, but the largest were apparently not more than 25–30 mm. in length; diameter of last whorl about 7–8 mm.

This species seems most closely allied to the Colorado variety of Stanton's *Turritella whitei*, and it is possible that those specimens should be included as a variety of our species. It seems to the writer, however, that the smaller size of our species, and the total absence of the finer intermediate revolving striæ, so far as seen, make them specifically distinct. Certainly our species must be regarded as undoubtedly distinct from the typical *T. whitei*, as

shown by the Utah forms, while the forms from Colorado seem to me to be more closely related to our species than to those from Utah.

Locality and Position. — Various places in the Galisteo Valley; most abundant in concretions in shales of Fort Pierre age, near wagon road just south of basalt-capped mesa, two miles southwest of Santa Rosa Mountain; also in the Fort Pierre (?) shales in Achavica Arroyo, one mile west of Grand Central Mountain. (Col. Univ. Coll. Pal., No. 14987.)

Strombidæ.

Genus ROSTELLARIA Lamarck.

ROSTELLARIA? TEXANA Conrad.

Rostellaria? texana Conrad 1857, Rep .U. S. and Mex. Bound. Surv., Vol. I., pt. 2, p. 158, pl. 13, figs. 4, *a*, *b*.

There is in the collection an internal mold which agrees closely with the one which Conrad referred to *Rostellaria?*, giving the specific name *texana*. The form of the volutions, the character of the depression near the suture, and the general outline of the specimen are identical with Conrad's type.

Locality and Position. — Achavica Arroyo, one mile northwest of Grand Central Mountain, in sandstones of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14988.)

Tritoniidæ.

Genus TRITONIUM Link.

TRITONIUM KANABENSE Stanton. (Pl. I., Fig. 6.)

Tritonium kanabense Stanton, 1893, Bull. U. S. G. S., No. 106, p. 150, pl. 31, fig. 12.

Of this beautiful species I have a number of examples, some of which are in a very good state of preservation. Our forms are larger than Stanton's type as a rule, but agree closely in other respects with his description. The spirals are strong, elevated, and flattened, and separated by broad interspaces, in which are seen from one to three fine lines, especially on the last whorl. The specimens vary in size, from those smaller than Stanton's type to forms whose length was not less than 40 mm.; and with a greatest breadth of 16 mm.

Locality and Position.—Near wagon road just south of basalt-capped mesa, two miles southwest of Santa Rosa Mountain, in shales of Fort Pierre age. One small specimen from the inclusion of Fort Pierre shales in lava half a mile west of Reservoir in San Marcos Arroyo probably belongs to this species. (Col. Univ. Coll. Pal., No. 14989.)

Volutidæ.

Genus ROSTELLITES Conrad.

Cf. ROSTELLITES AMBIGUA Stanton. (Pl. I., Fig. 7.)

Rostellites ambigua Stanton, 1893, Bull. U. S. G. S., No. 106, p. 156, pl. 33, figs. 8–10.

One poorly preserved internal mold seems most closely allied to this rather variable species, although the whorls are probably more convex. The suture was evidently slightly channeled, the surface ornamented with closely set spirals and transverse costæ, the latter nearly obsolete on body whorl.

Locality and Position.—Just north of Cerrillos in shales of Fort Benton age. (Col. Univ. Coll. Pal., No. 14990.)

ROSTELLITES DALLI var. WELLSI var. nov. (Pl. I., Fig. 13.)

Rostellites dalli Stanton, 1893. Bull. U. S. G. S., No. 106, p. 156, pl. 33, fig. 13. Not *Rostellites dalli* Stanton, *ibid.*, figs. 11 and 12.

Of this species I have but one specimen, collected by Mr. J. L. Wells from the shales near the eruptive core, in the northern part of the town of Cerrillos. The specimen is only fairly well preserved, the front portion of the shell and the apex being absent and the lips imperfect. Following is the description:

Shell of medium size, moderately slender, fusiform; spire elevated, less than aperture in length; volutions six or seven in number, convex, with narrow constriction below suture; body-whorl large, ventricose; shoulder angle prominent, especially on body-whorl. Surface ornamented with distinct moderately broad spirals, separated by somewhat narrower interspaces, and by prominent, rounded transverse costæ which become obsolete below the middle of the body whorl. On last revolution there are about twenty (eighteen shown and part of shell missing) spirals and ten of the transverse costæ. Aperture long and narrow, with slight

notch at posterior end, as indicated by lines of growth on shoulder; portion of shell near lips broken away. Apex not preserved.

Length of specimen when complete probably about 70 to 75 mm.; greatest breadth when complete, about 30 mm.

The shell agrees closely with the stouter individual figured by Stanton. Through the courtesy of Mr. Stanton I had the opportunity to examine his types, and was convinced of the identity of our form with the stouter variety. The spirals are rather broader in our form, although not nearly so much so as Stanton's figure would lead one to suppose. At the same time it seemed to me that the more typical forms of Stanton's types were entirely distinct from the stouter individual, and while the differences may not be specific, they certainly warrant the removal of that form to a distinct variety. In this opinion Mr. Stanton concurred, and on comparing our type with his stouter form, he regarded them as identical.

The variety is named for the collector, Mr. J. L. Wells. I am of the opinion that the specimens figured in the report of Herrick and Johnson on the Geology of the Albuquerque Sheet* have been wrongly identified.

Locality and Position. — Just north of Cerrillos, in shales of Fort Benton age. (Col. Univ. Coll. Pal., No. 14991.)

Cancellariidæ.

Genus ADMETOPSIS Meek.

ADMETOPSIS? ELEVATA sp. nov. (Pl. I., Fig. 14.)

Shell small, slender, subconical; volutions slightly convex, five or six in number; spire elevated, acute; suture slightly channeled; height of body whorl equal to about one half the total height of shell. Surface ornamented by small, low, rather closely set, transverse costæ, as well as by indefinite revolving lines; lines of growth also visible.

Length of average specimen, 13 mm.; breadth 6 mm.

Although this species is very abundant, it was not possible to secure a single perfect individual. The surface markings are only known from tiny fragments of shell still adhering to a few of the specimens, but it was seen that the spiral lines continue to the top of the body whorl, and are also present on the other whorls. In

* *Bull. Univ. New Mexico*, Vol. II., Pt. I., p. 37, Pl. III., figs. 3 and 5.

this respect our species differs from *A. rhomboides* Meek, to which it seems most closely related, as well as in its much more elevated spire, conical form, and less convex volutions. The presence of columellar folds is apparently indicated, but of this point I cannot be certain.

Locality and Position. — Near wagon road just south of basalt-capped mesa, two miles southwest of Santa Rosa Mountain, in shales of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14992.)

CEPHALOPODA.

AMMONOIDEA.

Lytoceratidæ.

Genus HELICOCERAS d'Orbigny.

? HELICOCERAS PARIENSE White.

For description and synonymy see Bull. U. S. G. S., No. 106, p. 164.

A very small weathered fragment is doubtfully referred to this species. The surface is marked by strong, rather abruptly rounded oblique annulations, which are less prominent on the inner side of the whorl, while there is doubtful evidence of nodes on the outer side.

Locality and Position. — Near wagon road just south of basalt-capped mesa, two miles southwest of Santa Rosa Mountain, in shales of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14993.)

Genus BACULITES Lamarck.

BACULITES ANCEPS Lamarck. (Pl. XI., Fig. 30, *a*, *b*, *c*.)

For description and synonymy see Rep. U. S. G. S. Terr., Vol. IX., p. 406.

There are a number of specimens of *Baculites* in the collection which are evidently identical with the Texas form referred by Dr. Roemer to *B. anceps*. In a few individuals the obscure ridges on the siphonal margin are a little more prominent than represented in Roemer's figures, but this character has been noted by Meek on forms regarded as identical with the Texas types. In some cases the shell itself is partially preserved, and the finer lines of growth beautifully shown. The septa are not sufficiently well preserved to be made out.

Locality and Position. — Near wagon road just south of basalt-capped mesa, two miles southwest of Santa Rosa Mountain, in shales of Fort Pierre age. One poorly preserved impression of this same species was found associated with *Inoceramus labiatus* and *Stantonoceras pseudocostatum* near the wagon road three miles northwest of Waldo. Fig. 30, *c*, is drawn from the cast of an impression found in the Fort Pierre sandstone one mile northwest of Grand Central Mountain, in Achavica Arroyo. The shell was evidently crushed, and is doubtfully referred to this species. (Col. Univ. Coll. Pal., No. 14993.1.)

BACULITES sp. undet.

Near the base of the Madrid section, one mile west of the town, were found a few specimens of *Baculites* whose characters are too poorly preserved to admit of identification. One badly altered individual comes from the inclusion of shales caught up in the lava half a mile west of the Reservoir in San Marcos Arroyo.

Amaltheidæ.

Genus PLACENTICERAS Meek.

PLACENTICERAS PLACENTA Dekay (sp)?. (Pl. VII., Fig. 26, *a*, *b*.)

For description and synonymy see Bull. U. S. G. S., No. 106, p. 169.

Associated with *Stantonoceras pseudocostatum*, in the shales northwest of Waldo, were several fragments of this species which seem closely identical with the New Jersey types. The shell was sometimes a foot or more in diameter, lenticular in form, with ventrum narrowly rounded to flat and aperture elongate sagittate. The septa are not well shown, but were apparently closely similar to those of the New Jersey forms, being less crowded than in the western types described by Meek.

Associated with *P.? intermedium* and *P.? rotundatum*, in the sandstones west of Madrid, I found one example which might belong to the smaller variety of this species which Stanton described from Colorado and Utah, or might be the young of the form described above. The septa are less crowded than in the larger western forms described by Meek. Our specimen has the flat narrow venter, smooth surface, and measures 120 mm. in greatest diameter, a portion of the shell missing.

Locality and Position.—The larger form is found in the Cretaceous beds near wagon road three miles northwest of Waldo. The smaller form came from one mile west of Madrid in strata of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14994 *a*, *b*.)

PLACENTICERAS ? sp. undet.

In the collection from northwest of Waldo are a few fragments of a form which resembles *P. placenta* Dekay in some respects, but which has more convex sides, faint lateral nodes near the periphery, and more rounded internal whorls, while the flat keel and more or less sagittate form of aperture still persist. This probably represents a distinct species, but until better material is available its relations cannot be determined. (Col. Univ. Coll. Pal., No. 14994 *c*.)

PLACENTICERAS? INTERMEDIUM sp. nov. (Pl. VIII., Fig. 27, *a*, *b*.)

Shell of medium size, sublenticular in form, sides of outer whorl progressively increasing in convexity; ventrum narrowly flattened, the flattened space bordered on each side by small, compressed, alternating nodes having their longer diameters parallel to the direction of the peripheral curve; these nodes becoming nearly obsolete on later portion of shell, where the ventrum is broader and more rounded; greatest convexity of outer whorl near umbilical angle; umbilicus small, volutions deeply embracing; umbilical angle fairly well defined, and provided with moderately strong pointed nodes; umbilical angle of inner whorls very marked, and provided with very small, faint nodes; a faint row of nodes beginning to show near ventral margin, especially on later portion of outer whorl. Surface showing obscure sigmoid lines of growth, and very faint traces of elongated prominences originating at the nodes along the umbilical and ventral margins. Septa similar to *Placenticeras placenta* Dekay, but simpler and not at all crowded.

Greatest diameter of type specimen, 110 mm.; greatest transverse diameter of body whorl, 35 mm.

The writer has in preparation a paper on the development of the *Placenticeratidæ*, in which the relation of this and the following forms will be treated in detail. At present I am only prepared to say that this species is descended from the same ancestors as the *P. placenta* of Meek, and that from the former (*P.? intermedium*) are descended the species described next below. The present form is closely related to *P. placenta* var. *intercalare* Meek, but the

two are very evidently not specifically identical. As to whether or not it should be classed under *Placenticeras* I am still uncertain. It is unquestionably intermediate in position between the immediate ancestor of the true *Placenticeras* and the genus *Stantonoceras* described below, but as to the exact value of its intermediate characters I am as yet in doubt.

Associated with this form, and directly descended from it, is the species *P.? rotundatum* described below.

Locality and Position.— One mile west of Madrid, in sandstone of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14995.)

PLACENTICERAS? ROTUNDATUM sp. nov. (Pl. IX., Fig. 28, *a*, *b*.)

Ammonites guadalupæ Gabb., 1872, Proc. Acad. Nat. Sci. Phila., for 1872, p. 264, pl. 9, fig. 1, pl. 10, figs. 1, 1*a*.

Not *A. guadalupæ* Roemer, Kreide von Texas, p. 32, pl. 2, fig. 1, *a*, *b*, *c*.

Shell of medium size, thick discoidal, sides of outer whorl convex; ventrum broadly rounded except on younger portion of whorl, where it is indistinctly truncated and bears small compressed alternating nodes; greatest convexity of outer whorl midway between umbilical and ventral margins; umbilicus small, volutions deeply embracing; umbilical angle rounded and provided with very strong pointed nodes; umbilical angle of inner whorls indefinite, and provided with strong, prominent nodes, which are partially concealed by the outer enveloping whorl; nodes near ventral margin fairly well developed. Surface marked by obscure sigmoid lines of growth and indefinite elongated prominences inclined forward from the nodes along the umbilical angle; fainter prominences directed back from nodes near ventral margin. Septa not well preserved, but evidently similar to typical *Placenticeras*, although less crowded.

Greatest diameter of type 120 mm.; greatest transverse diameter of outer whorl, 40 mm.

This form is the direct descendant of *P. intermedium*, but has so far advanced as to make it, in the opinion of the writer, specifically distinct. It may be distinguished from that form by the much greater thickness of the shell as a whole, the entire loss of sagittate form of aperture, the greater prominence of the nodes near the umbilical and ventral margins, the more rounded umbilical angle, the large nodes on the umbilical angle of the inner

whorls, the loss of the alternating nodes at a much earlier stage, and the more broadly rounded ventre.

That *Ammonites guadaloupæ* Roemer is descended from this form is also evident. But it seems to the writer that the former has so far advanced as to make it specifically distinct from our type. The typical *guadaloupæ* may be distinguished from *P.? rotundatum* by the much greater development of the nodes near the ventral margin of the former, the greater distance of the inner row of nodes from the umbilical suture (a result of the loss of the umbilical angle due to the distention of the shell below that angle by the increasing convexity of the next inner whorl), and by the fact that the youngest portion of the outer whorl is much more maturely developed than even a much later stage in our type.

As stated in the description of *P.? intermedium*, the reference of this species to *Placenticeras* is not final, and cannot be until the further study of more and better material is completed.

Locality and Position. — One mile west of Madrid, in sandstones of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14996.)

Genus STANTONOCERAS gen. nov.

Genotype. — *Stantonoceras pseudocostatum* Johnson.

Shell large in typical species; descended from the same ancestor as *Placenticeras;* having stages of growth corresponding to ancestral types which possessed, in successive generations, keels that were very narrowly flat, channeled, and alternately nodose; but so far advanced at maturity as to bear little or no resemblance to the typical *Placenticeras;* outer whorls broadly rounded or subquadrate in cross-section; moderately embracing; definite ventral keel nearly or quite obsolete; umbilical angle nearly or quite imperceptible; surface ornamented with more or less prominent nodes, elongated nodes or pseudocostæ; septa similar to those of *Placenticeras*, but more simple and less crowded.

Although somewhat less accelerated than the type of this genus, I am of the opinion that *Ammonites guadaloupæ* Roemer should be included here. It is of course one of the transition types, and its generic reference must be more or less a matter of judgment. But it has advanced so far from the original stock, and has so many features in common with this genus, that it seems to me impossible to classify it elsewhere.

? STANTONOCERAS GUADALOUPÆ Roemer (sp.).

Ammonites guadaloupæ Roemer, 1852, Kreide v. Tex., p. 32, pl. 2, fig. 1, *a*, *b*, *c*.

Associated with the ancestral types of this species, or possibly from a somewhat higher horizon, at the base of the Madrid section, was one very poorly preserved specimen which probably belongs here. Both the outer and inner rows of nodes were very highly developed, while the inner coils were apparently much more highly developed than in the closely related form, *P.? rotundatum*. Sigmoid lines of growth are well shown. The shell is too badly crushed to permit of accurate identification.

Locality and Position.—One mile west of Madrid, in sandstones of Fort Pierre age. (Col. Univ. Coll. Pal., No. 14997.)

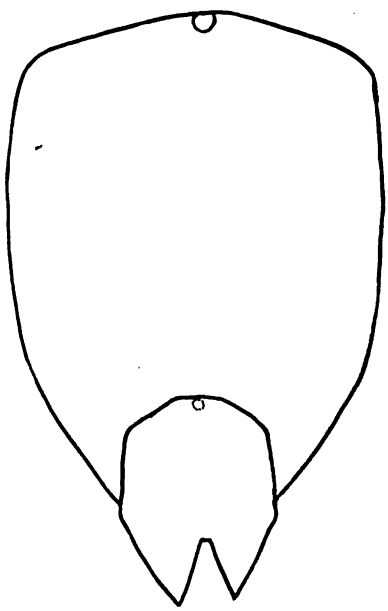
STANTONOCERAS PSEUDOCOSTATUM sp. nov. (Pl. X., Fig. 29, *a*; Pl. XI., Fig. 29, *b*, *c*.)

Shell large, outer volutions subquadrate in cross-section, embracing about one half of the next inner coil; venter broadly rounded, indistinct outline of narrow keel remaining; umbilical angle obsolete, shell thinning out gradually to a wedge-like form toward umbilical suture. Surface ornamented by prominent, compressed elevated ridges, formed by the elongation and coalescence of the nodes nearest the umbilicus with one of the outer series, while each of the remaining nodes of this latter series appears as a shorter ridge, between each two of the longer ones. These pseudocostæ are extremely prominent on the ventro-lateral angle, being high and broad, but decrease in prominence toward the umbilicus until about two thirds of the way across the side of the whorl, when they enlarge slightly, and then become obsolete. This last enlargement marks the position of the node which in ancestral types occurs at the umbilical angle. The septa are badly worn, making the sutures appear much simpler on some parts of the shell than on others, but enough remains to show that they were similar to those of *Placenticeras*, but not crowded.

From the standpoint of its development this species, which is only known from the portions of two outer whorls and the impression of the third inner one, is most interesting. The portion of the first inner whorl is figured on Plate XI., and it will be readily seen that it corresponds closely with the outer whorl of *S.* (*Ammonites*) *guadaloupæ* Roemer, except for the slight distortion pro-

duced by the enveloping whorl. This represents the *guadaloupæ* stage in the development of *S. pseudocostatum*. The nodes are here distinct, and show only the beginnings of the elongations which reproduce the form of costæ at a later stage. Traces of the narrow keel with the alternating nodes are distinctly seen on the rounded venter.

A wax impression of the next inner whorl is figured on Plate XI. Here we see the exact reproduction of the younger portion of the outer whorl of *Placenticeras? intermedium* Johnson, and have the *intermedium* stage in the development of *S. pseudocostatum*. The lenticular shape, narrowly truncated periphery, and alternating compressed nodes, having their longer diameters parallel to the peripheral curve, are well shown, even in so small a fragment. The accompanying figure shows the above stages as seen in cross-



Cross-section of *Stantonoceras pseudocostatum* Johnson. Reduced one half.

section. As I shall show more fully in the forthcoming paper, the intermediate stages can be carefully traced in other forms, as well as those stages preceding, in which latter case the further changes are (in reverse order) from the alternating noded keel to the channeled keel, then to the flat, and still earlier to the rounded

form. The development of the pseudocostæ will also be taken up in greater detail, but it is interesting to keep in mind the fact that costæ appearing much or quite the same in form, may have entirely different origins.

Locality and Position.—Near wagon road, three miles northwest of Waldo, in strata of Cretaceous age. (Col. Univ. Coll. Pal., No. 14998.)

Genus PRIONOCYCLUS Meek.

PRIONOCYCLUS WYOMINGENSIS Meek.

For description and synonymy see Bull. U. S. G. S., No. 106, p. 171.

Of this species I have only the impression of a portion of the outer (?) and an inner whorl, but the extreme irregularity of the costæ, the elongated nodes near the umbilicus, from which nodes two costæ frequently spring, and the smaller costæ between the larger nodose ones, leave no doubt as to the identity of the form.

Locality and Position.—Just north of the town of Cerrillos, in shales of Fort Benton age. (Col. Univ. Coll. Pal., No. 14999.)

PRIONOCYCLUS MACOMBI Meek.

For description and synonymy see Bull. U. S. G. S., No. 106, p. 172.

In the shales just north of Cerrillos were found one adult individual of this species and a number of young examples. In the adult the characteristic septa are fairly well shown, and the form and ornamentation agree in detail with the description and figures referred to, leaving no doubt as to its identity. Fragments of specimens 35 to 50 mm. in diameter show the minute crenulations of the keel and the strong nodes characteristic of the species at this stage.

Locality and Position.—North of the town of Cerrillos, in shales of Fort Benton age. (Col. Univ. Coll. Pal., No. 15000.)

PRIONOCYCLUS sp. nov. (Pl. I., Fig. 15.)

Associated with *P. macombi* and *Prionotropis woolgari*, in the shales just north of the town of Cerrillos, were found a large number of young ammonoids, usually so firmly imbedded in the matrix or so profoundly altered by metamorphism that only small fragments could be secured. These small individuals, an example of which is figured on Plate I., were at first doubtfully referred to

the young of *Prionocyclus macombi*, although they were seen to differ markedly from the figure of a young example of that species given on Plate XLI. of Stanton's paper. The following description of one of our forms may serve to make its relations clearer.

Shell discoidal, umbilicus quite narrow, volutions rather strongly embracing, compressed so as to be nearly flat on sides; periphery narrow, provided with a comparatively prominent, simple keel; surface of whorl ornamented with 75 to 100 (estimated from those counted on a fairly well preserved third of a volution) decidedly flexuous costæ, all of which reach the umbilical margin on the youngest part of the volution; but only every third or fourth one of which reach clear across the older portion, being rather swollen and prominent near the umbilical angle; on the periphery these costæ are bent rather abruptly and strongly forward. Diameter of type above described, 23 mm.; greatest convexity, 5 mm.; breadth of umbilicus, less than 4 mm.; breadth of outer whorl from siphonal to umbilical side, 11 mm.

A comparison with the adult of *P. macombi* will show that in these small individuals the umbilication is proportionately much greater and the costæ more flexuous — characters indicating a more accelerated stage of development than even the adult of that species. It is seen also that only every third or fourth costa reaches the umbilical margin and is there swollen and prominent — features which our specimens would seem to have in common with the adult of *macombi*. On the other hand the keel is still simple, and no nodes are developed, in which respects our specimens are noticeably less accelerated.

It might be considered that this type is the young of *P. macombi*, that species being a gerontic form in which the young would show more accelerated features. It does not seem to me, however, that the characters of the adult *P. macombi* warrant this assumption. Nor do I believe these forms can be considered the young of any known *Prionocyclus*. It is more probable that they represent the young of a species not yet known, which is closely related to *P. macombi*, but more accelerated in its development. The fact that a number of the young were found, but no adult, is not strange when it is considered that these fossils occur in metamorphosed shales close to the eruptive core, where everything is so crushed and altered that only smaller forms, or mere fragments of larger ones, are usually secured.

Locality and Position. — Just north of the town of Cerrillos, in shales of Fort Benton age. (Coll. Univ. Coll. Pal., No. 15001.)

Genus PRIONOTROPIS Meek.

PRIONOTROPIS WOOLGARI Mantell (sp.). (Pl. XII., Fig. 31, *a*, *b*, *c*.)

For description and synonymy see Bull. U. S. G. S., No. 106, p. 174.

Of this species I have two examples, one a well-preserved fragment of an adult specimen collected by Mr. J. L. Wells while excavating for the dust flues of the Cerrillos Smelter just north of the town. It was one of several fossils found in the loose shales near the eruptive core at this point, while the portion of a gerontic individual of the same species was collected at the same point by the writer. The former is by far the more interesting. The fragment (125 mm. in greatest length) is apparently a portion of the outer whorl of an individual some 160 or 180 mm. in diameter, the thickness at the smaller end of the fragment (from keel to keel) being 35 mm., at the larger end 50 mm., and the lateral thickness (through center of whorl, not including costæ) being 30 mm. at the smaller end, and 38 mm. at the larger. Nine costæ are shown, two of these being but partially developed. The keel is prominent and somewhat crenate, the nodes nearest it being compressed, their forward portions rising a little more prominently and terminating a little more abruptly than behind. The long axes of these nodes are approximately parallel to the keel, and are so strongly developed as to give the periphery, when seen in profile, the appearance of being deeply sulcated on either side of the latter. The costæ are rather pronounced, terminating at either end in prominent pointed nodes, those of the outer of the two series having the outermost compressed nodes of the third series near by. The two undeveloped costæ (separated by three of normal growth) become obsolete before reaching the line of the inner series of nodes, have the outer pointed nodes but slightly developed, with fairly prominent representatives in the flat compressed series. Faint indications of other secondary costæ may be noticed near the posterior ends of the flattened nodes of the more prominent costæ. The umbilical margin is deeply indented by the prominent nodes of the flattened series nearest the keel of the succeeding volution within. A portion of the siphuncle of this latter volution still adheres to the specimen in hand. Unfortunately not the slightest trace of the septa appears on this fragment.

A comparison of this individual with the figures given by Meek and others, shows that the nodes at the inner ends of the costæ of this specimen are very much more prominent and pointed than represented by them, being as strongly developed and as well preserved as those of the next outer series. As the accentuated development of the nodes may be safely looked upon as a progressive feature, we might infer that the individual under discussion represents a slightly more advanced stage of the evolution of this species. Another evidence of the advanced stage in the development of the species represented by this individual is found in its rather large size accompanied, however, by no gerontic characteristics. The larger specimens described by Meek, about the same size as the specimen under consideration, present unmistakeable old age characters. The outer compressed nodes have disappeared, the keel is only represented by distinctly separated, low, elongated nodes, the costæ are more distant and become pinched up at their inner extremities, not quite reaching the umbilical margin. In our specimen, however, the outer, compressed nodes are very prominent, the keel is continuous and well preserved, while the costæ are perfectly normal, and reach the umbilical margin, near which the inner nodes are strongly developed. All the evidence suggests a well preserved, normal adult individual, of a somewhat more advanced type than those represented by the figures referred to. The impression left on the umbilical margin by the next succeeding whorl within shows that this latter whorl represented, so far as can be told, essentially the same characteristics as the outer one; in other words, none of the characters of youth (such as the convex appearance of the ventrum due to comparatively prominent keel with adjacent compressed nodes which are but slightly developed) had persisted so late in the history of the individual. It is to be regretted that the validity of the evidences mentioned could not be tested by a comparison of the sutures.

If the specimen 160 to 180 millimeters in diameter represents a normal adult specimen in this more advanced stage of the development, we should expect gerontic individuals to be correspondingly larger. It was not surprising, then, to find at this same locality, and practically at the same horizon, a portion of an individual which must have measured from 250 to 300 mm. in its greatest diameter, presenting all the characters of gerontism. The outer

compressed nodes have apparently disappeared, the costæ are elevated and compressed, the inner nodes are almost entirely absent, while the next outer series is only represented by low rounded projections at the outer ends of the costæ. The costæ, however, continued to quite near the umbilical margin, which might be expected in a more advanced type where the inner nodes are so very highly developed in earlier life. The sutures are too poorly shown to be made out.

Locality and Position. — Just north of the town of Cerrillos, in shales of Fort Benton age. (Col. Univ. Coll. Pal., No. 15002.)

Stephanoceratidæ.

Genus SCAPHITES Parkinson.

SCAPHITES WARRENI M. and H.

For description and synonymy see Bull. U. S. G. S., No. 106, p. 185.

Of this species I have two impressions, only one of which is well preserved. The closely involute inner volutions and a part of the deflected body-portion are represented. As only a small part of the latter is shown, the greater prominence of every fourth or fifth costa, and the bifurcation of the same, which are characteristic of this portion of the shell, cannot be noted. Nevertheless the general features are such as to leave little doubt as to its identity. The shell must have been about 33 mm. in length, and 29 mm. in height.

Locality and Position. — Just north of the town of Cerrillos, in shales of Fort Benton age. (Col. Univ. Coll. Pal., No. 15003.)

VERTEBRATA.

PISCES.

TELEOSTEI.

Berycidæ.

Genus BERYX Cuvier.

BERYX sp. undet. (Pl. I., Fig. 12, *a*.)

Numerous fish scales in the shales north of Cerrillos are referred to *Beryx* on the basis of the characteristic markings they exhibit. Associated with them are scales of the form shown in Fig. 12, *b*, of whose identity I am in doubt.

Locality and Position. — Just north of the town of Cerrillos in shales of Fort Benton age. Also in shales of Fort Pierre age near wagon road just south of basalt-capped mesa, two miles southwest of Santa Rosa Mountain. (Col. Univ. Coll. Pal., Nos. 15004 and 15005.)

PLANTÆ.*

DICOTYLEDONS.

APETALÆ.

Urticaceæ.

Genus FICUS Linn.

FICUS RHAMNOIDES Knowlton. (Pl. XIV., Fig. 33.)

Ficus rhamnoides Knowlton, 1900, Flora of the Montana Formation, Bull. U. S. G. S., No. 163, p. 47, pl. 10, figs. 1–3; pl. 11, fig. 1.

To this species are referred one fairly well preserved leaf, and a few more fragmentary specimens whose identity is not so certain. The better preserved example shows the typical form, about equally narrowed base and apex, entire margin, rather thick, straight midrib, twelve pairs of secondaries, alternate, and at an angle of about 45 degrees with midrib. Nervilles not shown.

Length of leaf, 155 mm.; breadth, 60 mm.

Locality and Position. — Half mile east of Madrid, in sandstone of Fox Hills age, thirty feet above coal. (Col. Univ. Coll. Pal., No. 15006.)

FICUS UNCATA Lesqx. (Pl. XIII., Fig. 32.)

For description and synonymy see U. S. G. S. Terr., Vol. VII., p. 197.

Of this species I have one fragmentary leaf which shows the essential characters quite well. The leaf is large and broadly ovate; margin entire; immediate apex constricted upward into small acumen; midrib apparently channeled; secondary nerves close, parallel, camptodrome; nervilles but slightly oblique to secondaries.

In some aspects this specimen seems allied to *F. irregularis* Lesq. The midrib is hardly as thick as in the type of *F. uncata*, while the slight constriction of the immediate apex suggests *irregularis*, although the acumen is not nearly so pronounced as in that

* For the identification of the following species I am indebted to Mr. Frank Hall Knowlton.

species. In other respects the identity with the type of *uncata* seems complete.

Locality and Position.—Half mile east of Madrid, in sandstone of Fox Hills age, thirty feet above coal. (Col. Univ. Coll. Pal., No 15007.)

Cupuliferæ.

Genus QUERCUS Linn.

? QUERCUS sp.

In the red sandstones above the coal measures were found numerous fossil tree trunks, many of which were from one to two feet in diameter. They were usually weathered out and washed down in the arroyos, but some were seen lying horizontally imbedded in the sandstone. Thin sections from one of these fossil trees were examined by Mr. Knowlton, and I quote the following from his letter:

"The wood is a dicotyledon, and while it has been somewhat distorted by fossilization, it appears to be a species of *Quercus*. In any event it shows a highly organized dicotyledonous tree, wholly unlike anything known from the Jura-Trias, and might well belong to the Upper Cretaceous or later."

Locality and Position.—Two miles east of Cerrillos, in sandstones of Upper Cretaceous (?) age. (Col. Univ. Coll. Pal., No. 15008.)

POLYPETALÆ.

Araliaceæ.

Genus ARALIA Linn.

ARALIA? sp. (Pl. XIV., Fig. 34.)

Several fragments of leaves, one of which is figured, are referred to this genus with some doubt. These are found associated with the forms above described, in the Fox Hills sandstone above the coal, half a mile east of Madrid. (Col. Univ. Coll. Pal., No. 15009.)

PLATES.

PLATE I.

PAGE.

Aucella strongi sp. nov. 193

Fig. 1, *a*, *b*, *c*, *d*. Left valves, two thirds natural size.

Fig. 1, *e*. Small right valve, two thirds natural size.

Arca madridensis sp. nov. 194

Fig. 2. Type specimen, twice natural size.

Corbula nematophora var. *fitchi* var. nov. 198

Fig. 3. Right valve of typical specimen, slightly reduced.

?Solen cuneatus Gabb 197

Fig. 4. Portion of right valve referred doubtfully to this species.

Turritella galisteoensis sp. nov. 200

Fig. 5. View of average specimen (type), slightly reduced.

Tritonium kanabense Stanton 201

Fig. 6. Average sized specimen, slightly reduced.

Cf. *Rostellites ambigua* Stanton 202

Fig. 7. Internal mold apparently closely allied to this species, slightly reduced.

Scurria? coniformis sp. nov. 199

Fig. 8, *a*, *b*. Two views of type specimen, slightly reduced.

Acmæa cerrillosensis sp. nov. 199

Fig. 9, *a*, *b*. Two views of average specimen, three times natural size.

Ostrea anomioides var. *nanus* var. nov. 185

Fig. 10, *a*. Interior of large lower valve.

Fig. 10, *b*. Large upper valve.

Fig. 10, *c*. Exterior of average sized lower valve.

Fig. 10, *d*. Lower valve of a form probably belonging to this species.

All slightly reduced.

Lingula subspatulata H. and M. 185

Fig. 11, *a*. Specimen from Cerrillos district.

Fig. 11, *b*. Specimen from east of Ortiz Mountains.

Slightly reduced.

Beryx sp. undet. 215

Fig. 12, *a*. Typical scale of one of this genus.

Fig. 12, *b*. Example of scale found associated with above, but of unknown identity.

Rostellites dalli var. *wellsi*. var nov. 202

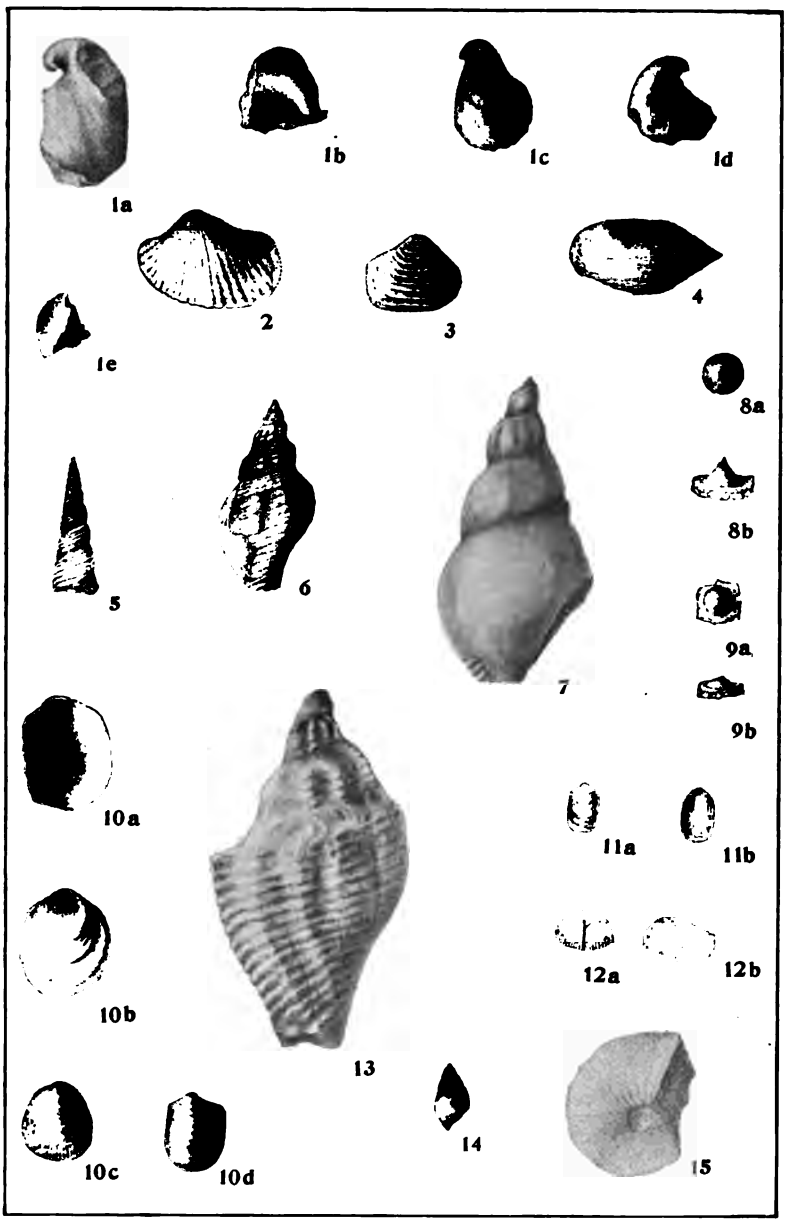
Fig. 13. View of type specimen, slightly reduced.

Admetopsis? elevata sp. nov. 203

Fig. 14. View of best preserved type specimen, slightly reduced.

Prionocyclus sp. nov. 211

Fig. 15. Best preserved example, with portions of keel broken away. Slightly reduced.



R. B. J. and D. W. J., Del.

PLATE II.

PAGE.

Inoceramus balchii M. and H. 189

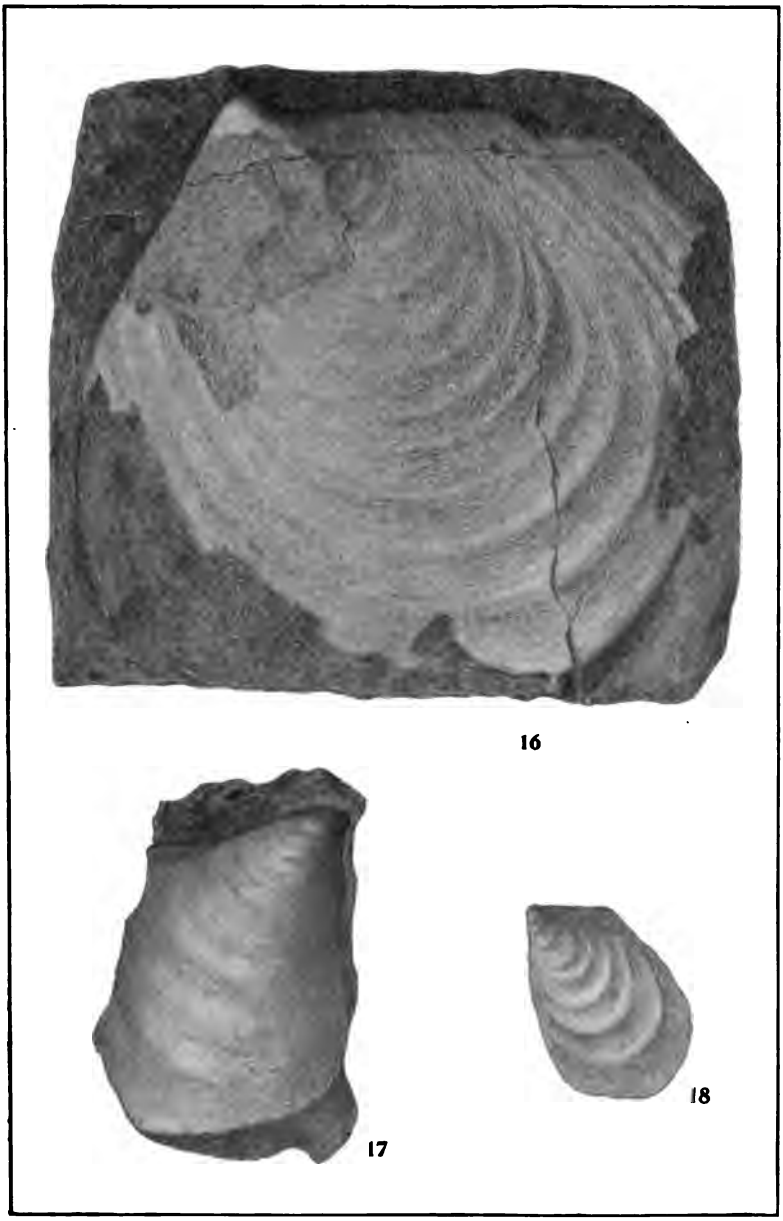
Fig. 16. Left valve, showing comparatively strong concentric undulations. Four fifths natural size.

Inoceramus fragilis H. and M. 187

Fig. 17. Internal mold of right valve. Four fifths natural size.

Inoceramus dimidius White 188

Fig. 18. Left valve, twice natural size.



16

17

18

R. B. Johnson, Del.

PLATE III.

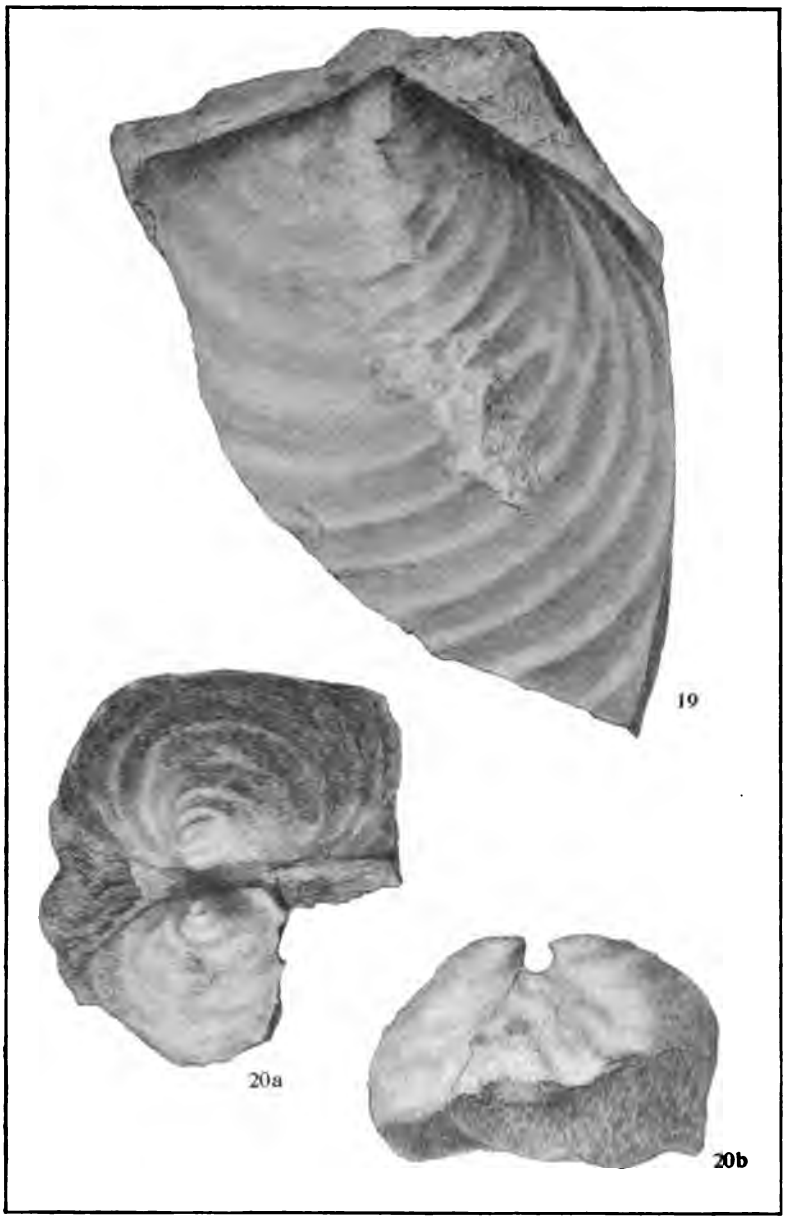
PAGE.

Inoceramus vanuxemi M. and H. 189

Fig. 19. Right valve, four fifths natural size.

Inoceramus sp. nov.? 190

Fig. 20, *a*, *b*. Two views of badly worn specimen, four fifths natural size.



R. B. Johnson, Del.

PLATE IV.

PAGE.

Inoceramus irregularis sp. nov. 190

Fig. 21, *a*, *b*. Two views of type specimen, four fifths natural size.

21a

21b

R. B. Johnson, Del.

PLATE V.

PAGE.

Inoceramus cripsii var. *barabini* Morton 190

Fig. 22. Portion of right valve, slightly reduced.

Enaocostea brooksi sp. nov. 192

Fig. 23, *a*, *b*. Two views of type specimen, four fifths natural size.

Astarte evansi H. and M. 195

Fig. 24, *a*. Internal mold.

Fig. 24, *b*. Portion of shell, showing character of ornamentation.

Fig. 24, *c*. Internal mold of young example.

23a

24a

24b

22

24c

23b

R. B. J. and D. W. J., Del.

PLATE VI.

PAGE

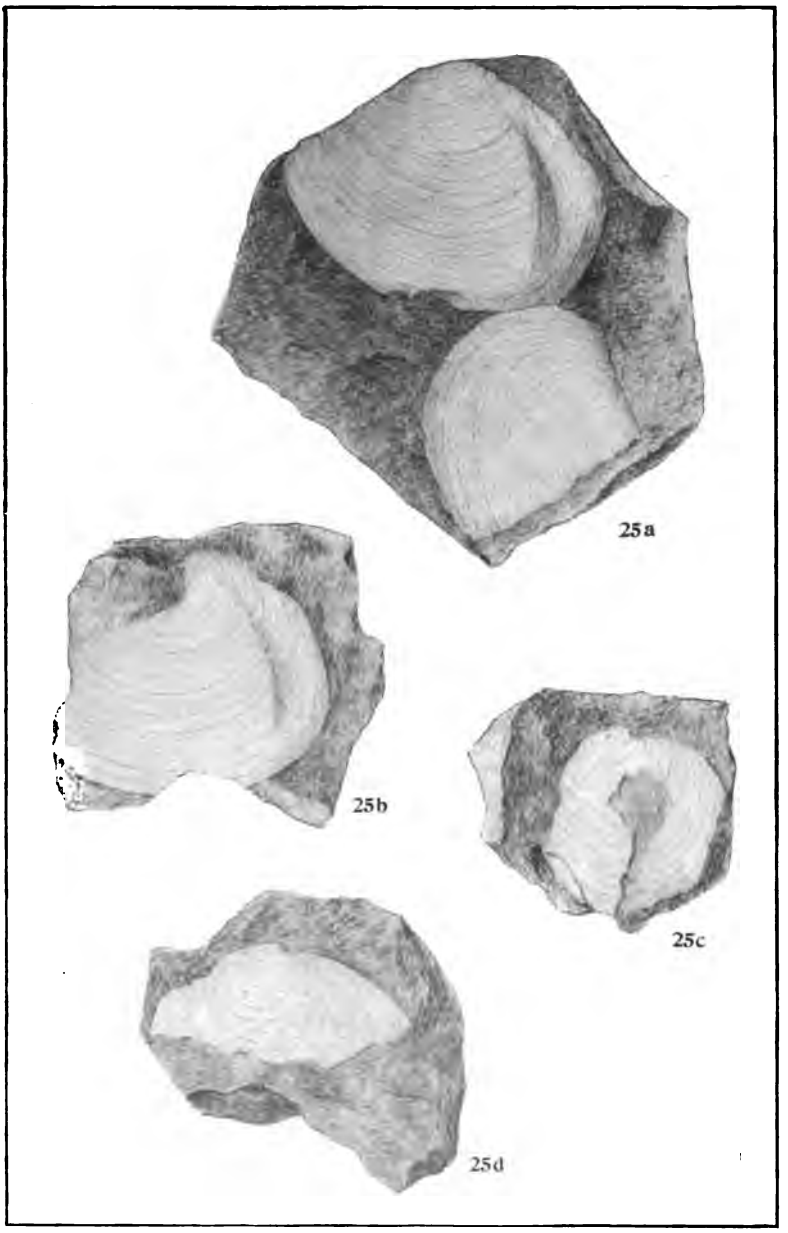
Cyprimeria ? sulcata sp. nov. 196

Fig. 25, *a*, *b*. Two internal molds showing sulcus, with surface markings impressed.

Fig. 25, *c*. Small right valve.

Fig. 25, *d*. Portion of average sized valve showing beak.

All slightly reduced.

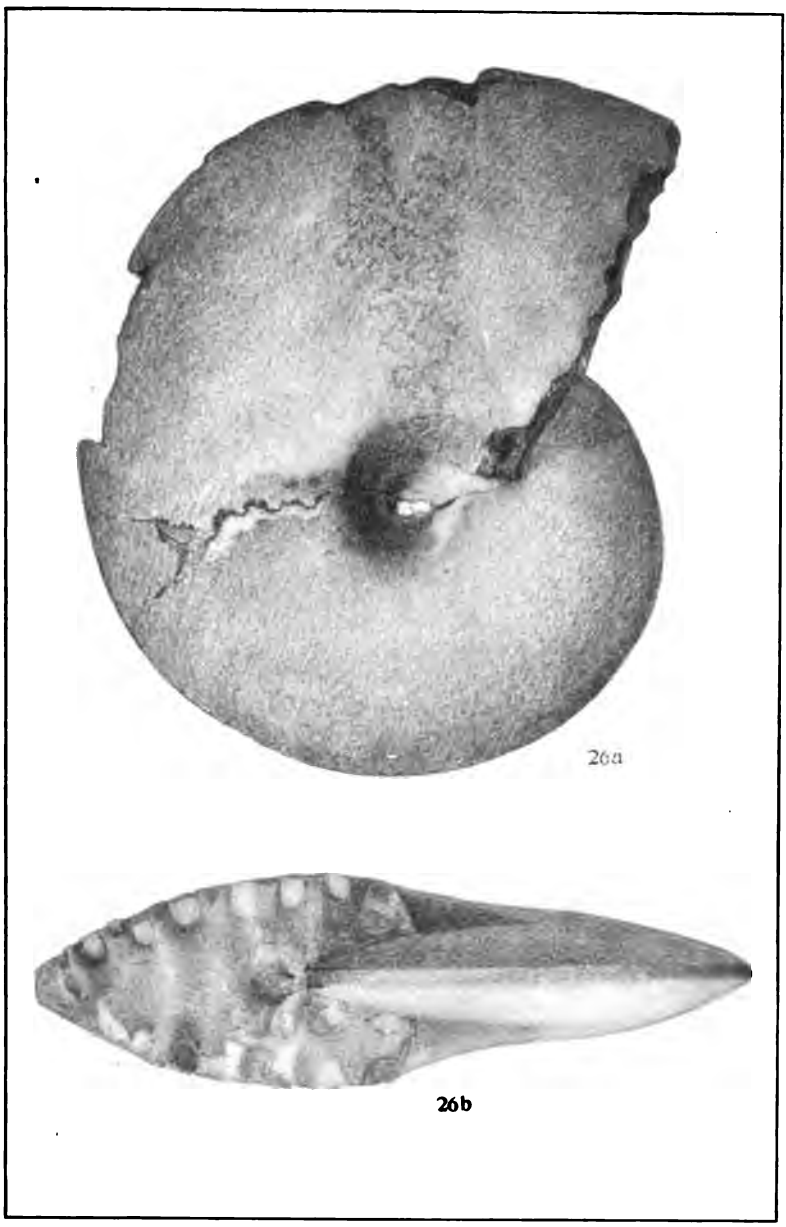


R. B. J. and D. W. J., Del.

PLATE VII.

PAGE.
Placenticeras placenta Dekay 205

Fig. 26, *a*, *b*. Two views of small specimen, four fifths natural size.

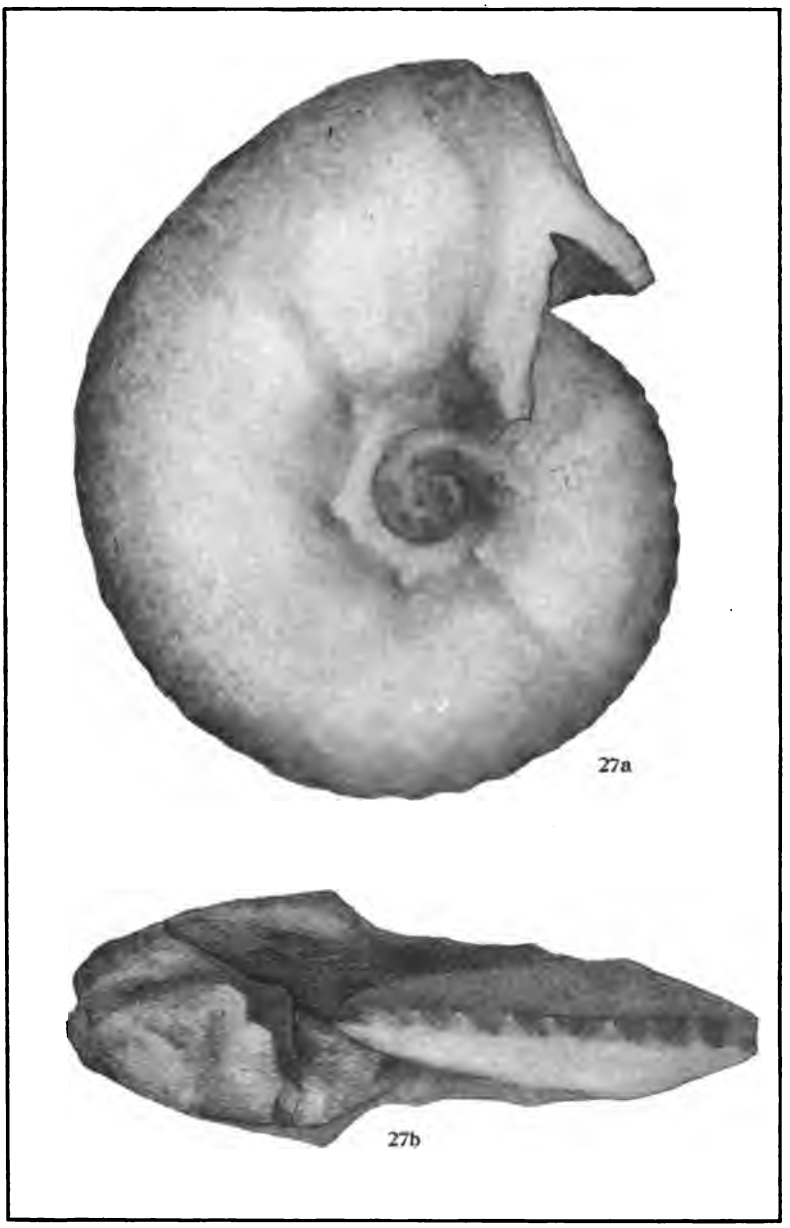


R. B. Johnson, Del.

PLATE VIII.

PAGE.
Placenticeras ? intermedium sp. nov. 206

Fig. 27, *a*, *b*. Two views of type specimen, four fifths natural size.



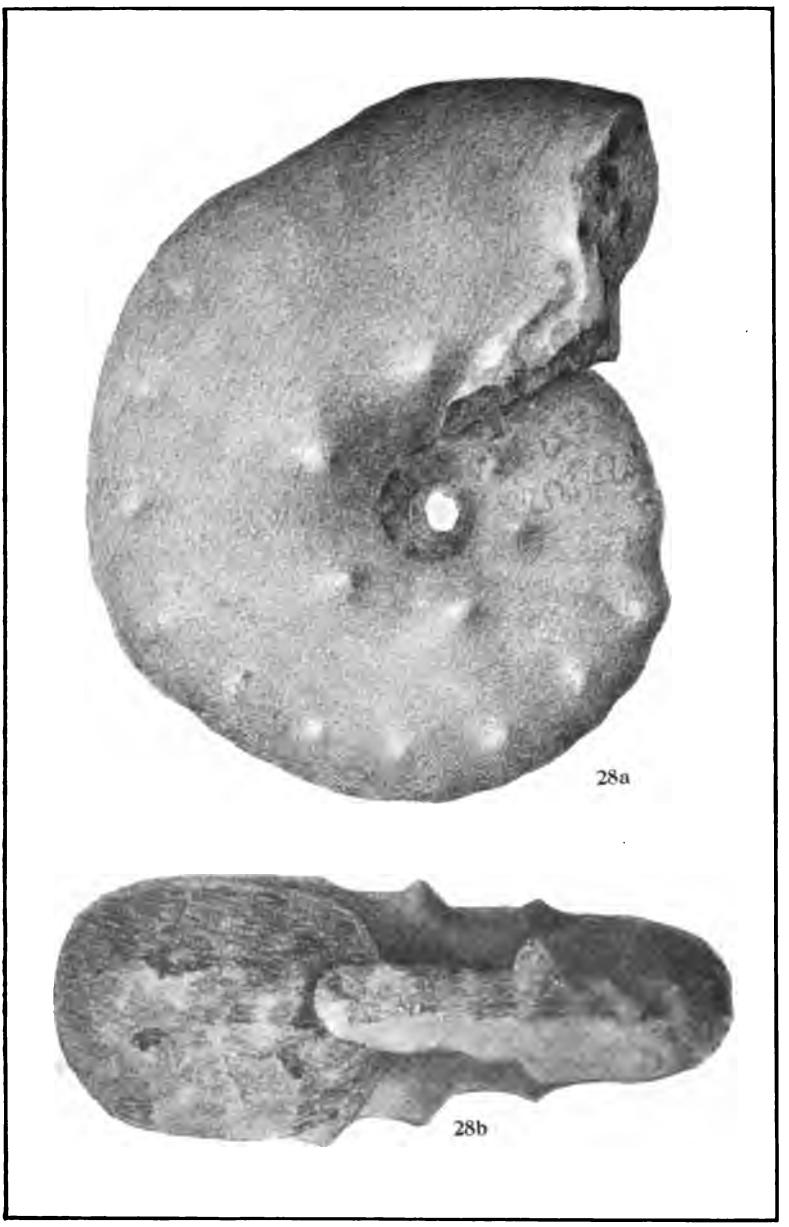
R. B. J. and D. W. J., Del.

PLATE IX.

PAGE.

Placenticeras? rotundatum sp. nov. 207

Fig. 28, *a*, *b*. Two views of type specimen, four fifths natural size.



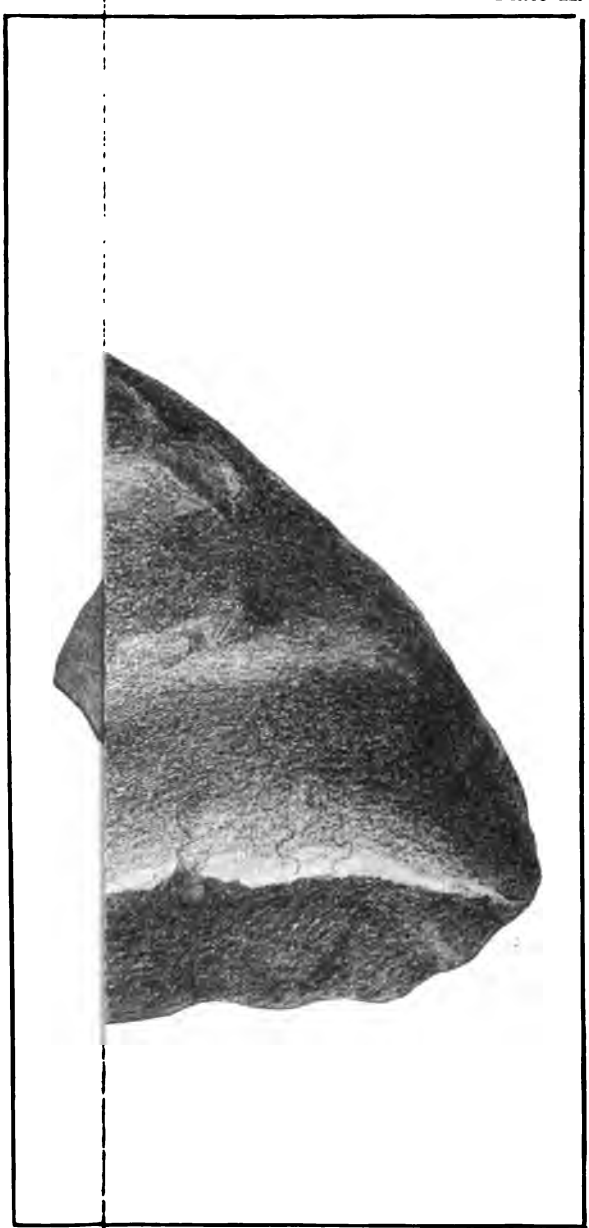
R. B. Johnson, Del.

PLATE X.

PAGE.

Stantonoceras pseudocostatum sp. nov. 209

Fig. 29, *a*. Portion of outer whorl of type specimen, four fifths natural size.
(See Plate XI.)



R. B. Joh

PLATE XI.

PAGE.

Stantonoceras pseudocostatum sp. nov. 209

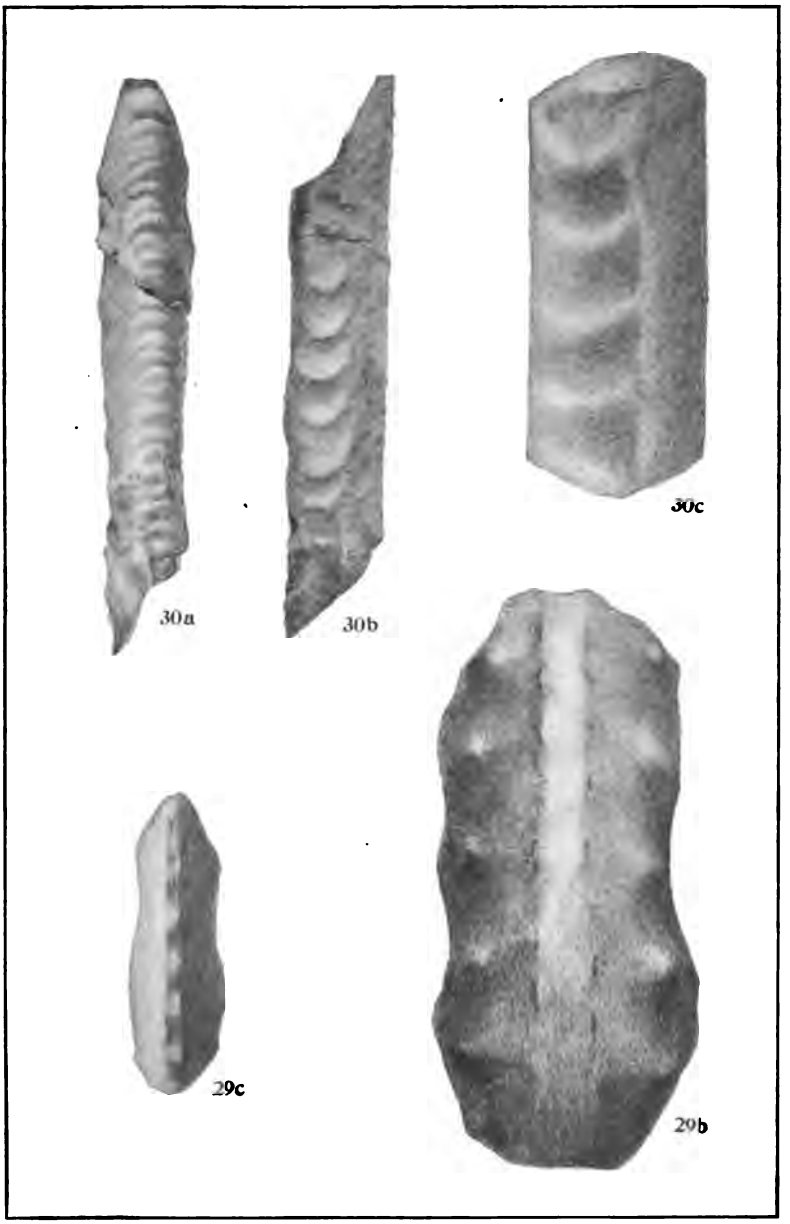
Fig. 29, *b*. Portion of first inner whorl of type specimen, four fifths natural size.

Fig. 29, *c*. Wax cast of portion of second inner whorl of type specimen, slightly reduced. (See Plate X.)

Baculites anceps Lamarck 204

Fig. 30, *a*, *b*. Two views of average specimen, four fifths natural size.

Fig. 30, *c*. Drawn from wax cast of an impression in sandstone doubtfully referred to this species. Four fifths natural size.



R. B. Johnson, Del.

PLATE XII.

PAGE.

Prionotropis woolgari Mantell 213

Fig. 31, *a*. Ventral view; nodes near umbilical angle showing most prominent in profile.

Fig. 31, *b*. Lateral view.

Fig. 31, *c*. Umbilical view, showing portion of siphuncle still adhering, and the prominent nodes near umbilical angle. Outer series of lateral nodes not visible.

Plate XII.

31c

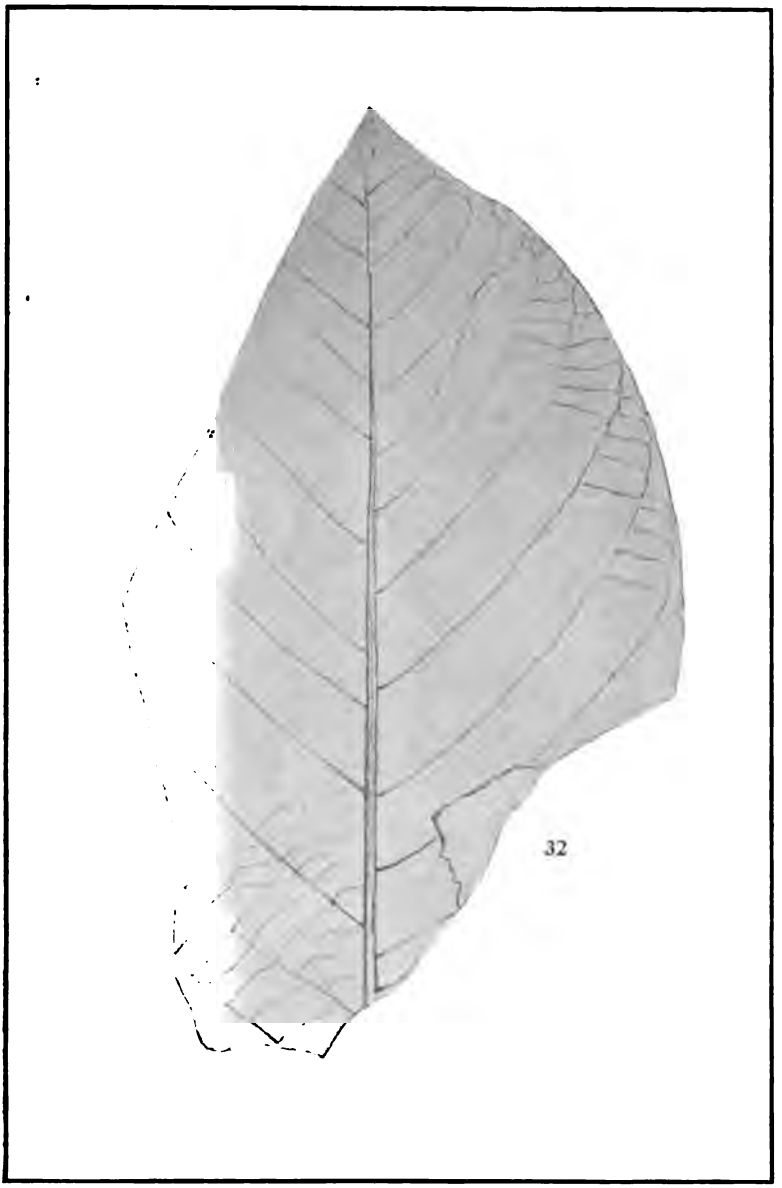
R. B. Joh

Plate XIII.

Page.

Ficus uncata Lesqx. 216

Fig. 32. Portion of a large leaf of this species, four-fifths natural size.



R. B. Johnson, Del.

PLATE XIV.

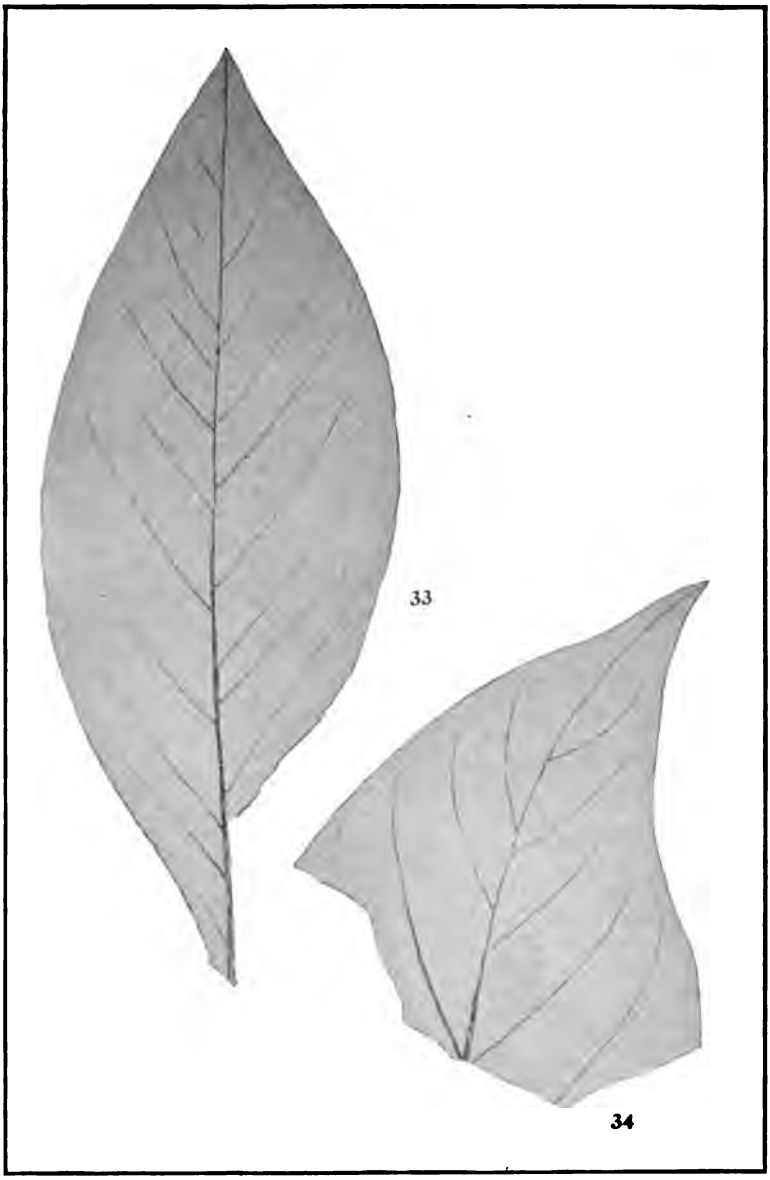
PAGE.

Ficus rhamnoides Knowlton 216

Fig. 33. Best preserved specimen, four-fifths natural size.

Aralia? sp. 217

Fig. 34. One of the best preserved fragments referred doubtfully to this genus. Four-fifths natural size.



R. B. Johnson, Del.

NOTES ON RECENT MINERALOGICAL LITERATURE.

By ALFRED J. MOSES AND LEA McI. LUQUER.

I. CRYSTALLOGRAPHY AND GENERAL MINERALOGY.

Optical Characters and Tests.

Koenigsberger, Joh.—Zur optische Bestimmung der Erze, *Centbl. f. Min. Geol. u. Pal. 1901, No. 7*, 195.

By placing a Savart plate (two calcite plates cut at 45° to the optic axis and crossed, so that the interference lines are central above the objective and using a vertical illumination from a lamp and an upper nicol the partial polarization of the light when reflected from either crystal faces or fairly polished cut surfaces of opaque but anisotropic substances is sufficient to develop the interference fringes, which disappear and attain a maximum four times during a revolution of the stage, and in some degree also to indicate the principal vibration directions. The author hopes to further develop the method. — A. J. M.

A. Harker. — On a question relative to extinction-angles in rock-slices. *Min. Mag.*, 13, 66, 1901.

A mathematical discussion. Author shows that in rhombic columnar (parallel to c) crystals, sections with small obliquity to c "will not give any considerable departure from straight extinction, except when $2V$ is a wide angle" (over 120°). — L. McI. L.

Rinne, F. — Bestimmung des Charakters der Doppelbrechung im convergenten polarisirten Lichte mit Hülfe des Gypsblattchens vom Roth 1° Ordnung. *Cbl. f. M. G. u. P.*, No. 21, 647, 1901.

That the use of the gypsum plate for determining the character of double refraction in uniaxial crystals by the position of the blue quadrants may be extended to those sections of biaxial crystals in which the optic axes emerge. The plate must be in normal position, the axes either left to right or front to back, then, as in uniaxial, the red of the gypsum is made blue in the positive quadrants if the double refraction is positive, and in the negative quadrants if the double refraction is negative.

Good examples demonstrating the method are cleavages of muscovite, negative, and heulandite, positive. — A. J. M.

Wulfing, E. A. — Ueber einen vereinfachten Apparat zur Herstellung orientirter Krystallschliffe, *N. J. f. Min., etc.*, 1901, II., 1–22.

The fine apparatus of Tutton costs about $450. The herein described form is accurate within 2′ and is simple in construction, but the cost is not given.

It consists of a steel grinding tripod, one of the feet serving as crystal carrier. The tripod is moved back and forth by hand on a horizontal piece of glass on which is the polishing powder. Upon this grinding tripod rests a second tripod with a level; the level is therefore always parallel to the grinding surface and its feet in positions corresponding to those of the grinding tripod. The crystal is approximately adjusted

by the eye and a slight face ground. A freehand projection of this and the reference faces is then made as a guide and the necessary correction made on the levelling tripod but *in the contrary sense* and then relevelled by the screws of the grinding tripod. Many details are given in the article. — A. J. M.

Keilhack, K.—On the Phosphorescence of Minerals. *Verh. d. deuts. geol. Gesellsch*, 1898, p. 131.

Author finds that the luminosity of different minerals will vary greatly under the action of the Röntgen rays. Minerals of the same species but from different localities will also vary in this regard, there being a marked difference between the fluorite from Zinnwald and that from Rabenstein. Anhydrite is found to respond to these rays while gypsum does not.

A table of relative luminosity from 0–64 has been arranged, Brazil topaz being 0 and colorless Rabenstein fluorite 64.

The color of the phosphorescence is found to be yellowish with apatite, greenish with fluorite, bluish with diamond, and yellowish and without particular characteristics with the other minerals.—L. McI. L.

Afanasséeff.—Action des minéraux contenant de l'uranium et du thorium sur les plaques photographiques. *Jour. de la Soc. Chim. russe*, XXXII., 103, 1900.

Author considers that loranskite, which acts on photographic plates and does not contain uranium or thorium, probably contains a new element.

F. Rinne.—Liquid air as a means of refrigeration in crystallographic investigations. *Cent. f. Min.*, 1902, p. 11.

By means of liquid air a temperature of $-180°$ can be obtained. Experiments with crystal sections show that the axial angle, etc., will vary with decreasing temperature. The axial angle of gypsum, for example, becomes much larger.—L. McI. L.

Crystal Structure and Symmetry.

Viola, C.—Zur begründung der Krystalsymmetrien. *Zeit. f. Kryst.*, 34, 353–388, 1901.

Viola would find a basis for the divisions of crystal symmetry in the physical characters rather than in either theories of homogeneous structure and the possible arrangement of points in space or the purely geometric conception of simple rational indices. As to the correctness of the law of rational indices the results of measurement show in the most perfect crystal slight deviations in angles and in zones and though this might be attributed to slight errors, there are undoubtedly plane faces as well as curved faces which have no rational indices. As to structure theories they are as yet mere mathematical conceptions.—A. J. M.

W. Barlow, H. A. Miers and G. F. H. Smith. — The Structure of Crystals: Part I. *Report on the Development of the Geometrical Theories of Crystal Structure*, 1666–1901. British Association for the Advancement of Science. Glasgow meeting, 1901, Section C, 41 pp. A very complete work dealing both with the historical development of the subject and also with the geometrical theories of structure.

Beckenkamp, J.— Zur symmetrie der Krystalle. *Zeit. f. Kryst.*, 34, 569–611, 1901.

The writer discusses the structure of quartz, cristobaltite, tridymite, halite, sylvite and fluorite and the hemimorphism of quartz, tridymite and calcite.

Hilton, H.— A comparison of the different symbols used in the theory of crystal structure to designate the 230 types of structure. *Cbl. f. M. G. u. P.*, 1901, No. 24, 746.

Kraus, E. H., and Mez, G.— Ueber topische Axenverhaltnisse. *Zeit. f. Kryst.*, 34, 389–396, 1901.

Formulæ are deduced for calculating Muthmann's Topic axial ratios, (see Focks Chemical Crystallography, p. 98) for triclinic, and hexagonal crystals.

Crystal Growth.

T. W. Richards.— Study of the Growth of Crystals by the Method of Instantaneous Microphotographs. *Phil. Mag*, 2, 488, 1901.

The photographs show that the smallest elements visible are crystallized.

L. McI. L.

Wulff, G.— Zur Frage der Geschwindigkeit des Wachthums und der Auflösung der Krystallflächen. *Zeit. f. Kryst.*, 34, 449–530, 1901.

The investigation undertaken was to: (1) Measure the velocity of growth of the different faces of crystals of a given material. (2) To measure the velocity of solution of the faces of these crystals in the mother liquor from which they developed. (3) From these to deduce the relations between the velocities of growth and solution. A crystal forming in a solution draws to itself only the molecules which are in the liquor immediately surrounding it; it exerts no influence at a distance. Two factors explain the constant renewal of material: (*a*) The diffusion from without into the impoverished layer of the more strongly concentrated solution. (*b*) In energetic crystallization diffusion has not time to act and it would seem that the immediately surrounding layer becoming specifically lighter, rises and is replaced by a new portion of concentrated solution thus giving rise to concentration currents.

In order to study these currents Toepler's method was used in which every disturbance of the optical homogeneity in or near is made visible, on a translucent screen, to the eye or the camera directly behind it. For simplicity the lens was replaced by a common cylindrical crystallizing glass filled with liquid. Some of the conclusions obtained by a study of the photographs were: (*a*) With feeble concentration currents the crystal grows much more regularly than with strong currents. (*b*) The currents tend to round the crystals and are the cause of the phenomena of vicinal faces. (*c*) The limitation of growth is also a function of these currents, for as the concentration of the solution decreases the layer near the crystal rises more and more slowly. (*d*) The velocity of growth depends on inclination of the face to the horizon and a comparison of growth velocities can be made only when the faces compared are similarly oriented with respect to the concentration currents.

In order to determine the relative velocities of growth normal to different faces two isomorphous salts of different color were selected, crystals of the less soluble salts were sorted into groups according to faces and fastened to the cover of the crystallizing dish, the dish being filled with a concentrated solution of the more soluble salt. Later the thicknesses of the added crust of this second salt were measured.

For the salt studied $Fe(NH_4)_2(SO_4)_26H_2O$, there were great differences in growth velocity, the simpler faces growing more slowly. If that of cube is taken as unity the results were: (001) 1, 00; (111) 1, 96; $(20\bar{1})$ 2, 25; (310) 2, 50; $(11\bar{2})$, 2, 64; (211), 2, 77.

On the other hand when solution velocities were determined they were almost equal for different faces.

To remove the effect of the concentration currents the same cylindrical glass vessel was hermetically sealed and rotated about its own axis, horizontally placed, a single crystal having previously been mounted therein in a definite position. The results thus obtained were somewhat nearer together than before but the differences in growth velocity were still great.

The apparent cause of lack of a reciprocal relation between the velocities of growth and solution is that at every stage of growth the faces are perfect planes, whereas in solution the faces become pitted with etch figures each of which is an aggregate of faces of different crystalline characters.—A. J. M.

Meyer, S.—Sur la cristallisation dans un champ magnétique. *Akad. Vienne*, CVIII., 513, 1899.

Photographs of crystal forms of the sulphates of cobalt, zinc, and manganese and of the chloride of cobalt, when crystallized in a magnetic field, show a variation from those crystal forms produced under normal conditions.—L. McI. L.

Crystal Measurement and Calculation.

H. Hilton.—A simple proof of the rationality of the anharmonic ratio of four faces of a zone. *Min. Mag.*, 13, 69, 1901.

Moses, A. J., and Rogers, A. F.—Formulæ and Graphic Methods for Determining Crystals in terms of Coördinate Angles and Miller Indices. *Sch. Min. Quar.*, 24, 1–36, 1902.

Methods for determining the morphology of crystals in terms of coördinate angles and Miller indices, making use of stereographic projections and new graphic solutions. Measurement with the two-circle goniometer and construction of stereographic projection by means of the protractors and sheets of Penfield are described in some detail. In the complete determination of a crystal there are three steps in the calculation: (1) Determination of indices from the measured angles; (2) determination of axial elements from indices and measured angles; (3) determination of theoretical angles from indices and axial elements. A graphical method suffices for the determination of indices, one step of the calculation is dispensed with and a check is made upon the rest of the calculation. The graphic method consists of the determination of the ratios $h:k$, $k:l$ and $h:l$ for all forms. These values as found are terms of a unit scale and approximate rational numbers almost as closely as do those of calculation. For the second and third stages of the calculation formulæ (in most cases new) have been given.

Formulæ for transformation to any new polar plane and new meridian and for determination of twinning plane are also developed. Each of these has a graphic solution. Finally after a brief discussion of projection from interfacial angles, formulæ for obtaining coördinate angles from interfacial angles are given.—A. F. R.

Penfield, S. L. — Solution of Problems in Crystallography by means of Graphical Methods, based upon Spherical and Plane Trigonometry. *Amer. Journ. Sci.* (4), 14, 249–284, 1902.

Calls attention to the desirability of graphic methods in crystallography for they serve as a check on calculation or in the case of known forms do away with calculation altogether. Makes use of stereographic projection and uses sheets and protractors described by him in a previous article. The methods of solving some general problems, such as finding the fourth face of a zone, are indicated. Each system is taken up in some detail and examples are given under each. The method consists in determining the ratios $k:h$ and $h:l$ or $k:l$ in each vertical zone. Indices are not given in terms of any unit scale but it is necessary to calculate them though the calculations are usually mental. — A. F. R.

G. F. Herbert Smith. — Preliminary Note on an Improved Form of three-circle Goniometer. *Min. Mag.*, 13, 75, 1901.

To provide for the possibility of measuring through 180° from a pole in the zone of reference over the upper half of the crystal to the diametrically opposite pole; the author proposes to have telescope and collimator combined into an "autocollimating telescope," the tube of which is bent through a right angle in the horizontal plane. — L. McI. L.

Klein, C. — Das Krystallpolymeter. *Zeit. f. Instrument.*, July, 1902.

As built by Fuess this instrument will measure crystal angles by one, two or three circles, will determine indices of refraction by either prism or total reflection methods, measure axial angles and serve for the study of thin sections by either parallel or convergent light. Its greatest convenience is that it permits so many tests upon a definitely oriented crystal. — A. J. M.

Mineral Synthesis.

A. de Schulten. — Reproduction artificielle de la monétite. *Bull. Soc. Min.*, 24, 323, 1901.

Pure, determinable crystals obtained by the very slow action of ammonia and phosphate of calcium in a hydrochloric acid solution, the solution being warm. The artificial triclinic crystals are described. The specific gravity is 2.928 at 15°, that of the natural mineral 2.75.

Author points out the strong similarity between monetite and martinite, and suggests that they may prove to be identical. L. McI. L.

Melting Points.

Doelter, C. — Ueber die bestimmung der Schmelzpunkte bei Mineralien und Gesteinen. *Tschermak's Min. Mitt.*, 21, 211. Die Schmelzbarkeit der Mineralien und ihre Löslichkeit in Magmen. *Ibid.*, 307.

The writer uses two methods for determining melting points: (1) Simultaneous smelting of mineral and salt of metal of known melting point. (2) By pyrometric methods using principally the thermo-element of Le Chatelier, dipping the element in the mineral powder in a platinum crucible and reading the galvanometer at the time the powder softens.

Five to ten observations not differing more than 10–20 degrees are needed safely to determine the point at which the material passes from the crystalline state to the amorphous. Fritting sometimes begins over

100 degrees below the melting point. The temperatures for the thin-fluid condition and for resolidification may also be determined.

The melting points of the rock-forming minerals lie mostly between 1000–1300, only a few like the zeolites, soda pyroxenes and soda hornblendes lie under 1000 and only a few like bronzite, quartz, corundum and olivines, poor in iron, over 1300. The greater number lie between 1050–1200. Tests on the plagioclases, confirmed Retger's rule, the melting points being continuous functions of the percentage composition. With rocks, softening is often only an indication that the melting point of one constituent has been reached. Complete liquefaction may require much higher temperature.

The melting points of mixtures of minerals were found to be very exactly the mean of the melting points of the constituent minerals except in the case of a mixture of orthoclase 50, quartz 25, and muscovite 25, which softened at about 1180, though at 1210 most of the quartz was still undissolved.

The order of solubility or fusion in granites was first magnetite and micas and hornblendes rich in iron, then other silicates, then plagiocase, then orthoclase and last quartz.

A series of observations on the solubilities of minerals in melts of different rocks led to the conclusions that the principal factor was the chemical composition and proportions of the magma, but that the viscosity of the melt and the melting point of the mineral also affect the solubility.

A. J. M.

Rock Analyses.

Washington, Henry S.—The Statement of Rock Analyses. *Am. Jour. Sci.*, iv., X., 59, 1900.

The following method, inaugurated by Pirsson, is probably the best for petrographers, the constituents being stated as oxides: SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, CaO, Na_2O, K_2O, H_2O(ignit), H_2O(110°), CO_2, TiO_2, ZrO_2, P_2O_5, SO_3, Cl, F, S(FeS_2), Cr_2O_3, NiO, CoO, MnO, BaO, SrO, Li_2O.

Uniformity in analytical reports would greatly aid in the comparison of rock analyses and the increasingly important chemical investigation of rocks.

Author urges the printing of the important molecular ratios with each new analysis.—L. McI. L.

Chemical Mineralogy.

F. W. Clarke and G. Steiger.—The action of Ammonium Chloride upon Certain Silicates. *Am. Jour. Sci.*, iv., 13, 27, 1902.

The finely powdered mineral was mixed with four times its weight of dry ammonium chloride and then heated for some time in a sealed combustion tube to 350°. After cooling and leaching with water the air-dried residue was analyzed

Stilbite, *heulandite* and *chabazite* proved not to be hydrous metasilicates, but probably trisilicates with the mixture of a few orthosilicate molecules.

Thomsonite is essentially an orthosilicate.

The water in all these cases has been assumed to be "zeolitic."

The three iron silicates, *thvaite*, *riebeckite?* and *ægirite* were very dif-

ferently attacked by ammonium chloride, ilvaite most strongly and ægirite very feebly, and did not form ammonium derivatives. Ægirite showed the most stable molecule.

Phlogopite was somewhat attacked by ammonium chloride but *serpentine* and *leuchtenbergite* scarcely at all. None formed ammonium derivatives.—L. McI. L.

C. Steiger.—Preliminary Note on Silver Chabazite and Silver Analcite. *Amer. Jour. Sci.*, iv., 14, 31, 1902.

Tests show that some of the natural silicates, supposed to be very refractory, are easily attacked and replacements effected.

H. N. Stokes.—On Pyrite and Marcasite. *Am. Jour. Sci.*, iv., 12, 414, 1901.

Author criticises A. A. Julien's density method for determining the relative proportion of these minerals present, and also his theory that even crystallized specimens of these minerals are often paramorphs. The following method is advocated for distinguishing pyrite and marcasite and for quantitative determination in case of mixtures: Under proper chemical treatment the percentage of sulphur oxidized by ferric salts, in the case of pyrite and marcasite, differs radically, being p (*oxidation coefficient*) $= 60$–61 in pyrite; 16.5–18 in marcasite. The method is too complicated, however, for quick mineralogical determinations.

By preparation of artificial mixtures a *curve* has been obtained, yielding the pyrite per cent. in a mixture, based on the value of p. Many finely fibrous specimens, passing as marcasite, have been proved pyrite by this method.

A. A. Julien, in *Science*, new ser., vol. 15, No. 387, 1902, ably defends his statements regarding paramorphs of pyrite and marcasite and his theory that the density affords a criterion for composition; and questions the assumption of the purity of the specimens in Stokes' tests.

L. McI. L.

W. Tarassenko.—Note sur la constitution chemique des plagioclases calcosodiques. *Bull. Soc. Min.*, 24, 269, 1901.

The results of analyses and extinction angles (many of which are recorded) confirm the theory that the lime-soda plagioclases are definite compounds of the Ab and An molecules and not simply isomorphous mixtures.—L. McI. L.

Struver, J.—Eine chemische Reactionen zwischen Hauerite und einigen Metallen bei gewöhnlichen Temperatur. *Cbl. f. M. G. u. P.*, 1901, No. 9, 257. Chemische Reaction der natürlichen Eisensulfide und des gediegenen Schwefels auf Kupfer und Silber bei gewöhnlichen Temperatur. *Ibid.*, No. 13, 401.

Some Raddusa hauerite crystals were accidentally shut for ten years in a pasteboard box with a piece of pure metallic silver. On opening the box the crystals were much more altered than other hauerite crystals placed in the collection at the same date and the silver was coated with a thin blackish crystalline layer. Experiments made by placing fragments of hauerite crystals on polished silver coins and on pure silver and pure copper showed that the pure metals were very much more rapidly attacked than the coin alloy. In a later series of tests using other sulphides, pyrite acted very slowly and marcasite much more rapidly on copper and on silver but not on other metals, while arsenopyrite and cobaltite did not

act on any metal. Similar negative results were obtained with stibnite and orpiment. In proof that H_2S is not formed, crystals were coated with white lead and laid on the metal. The latter blackened but the white lead did not.—A. J. M.

Group Discussions.

Eisenhuth, K.—Beiträge zur Kentniss der Bitterspäthe. *Zeit. f. Kryst.*, 35, 582–607, 1902.

An elaborate study of the rhombohedral carbonates found in the talc and chlorite slates of the Alps. The same material being used for analysis, density, crystal measurement and where possible optical determination. For the latter the following method was used: Three-sided prisms were cut, the end parallel to base and the angles about 30°, 60° and 90° and for any angle each face was taken as entrance face.

The results are tabulated. Some general conclusions are: That in all of the thirty-five specimens examined the lime contents are constant and it is only the magnesia that is replaced by the oxides of iron or manganese, so the general formula is $Ca(Mg, Fe, Mn)C_2O_6$.

That with increased iron the obtuse angle between the edges of the rhombohedron increases as do also the density and the indices of refraction. — A. J. M.

G. T. Prior and L. J. Spencer. — The Cerargyrite Group, holohedral-cubic silver haloids. *Min. Mag.*, 13, 174, 1902.

Results show that the chloride, bromide and iodide of silver can form isomorphous mixtures in varying proportions, but the limiting amount of I is indicated by the ratio Cl : Br : I = 1 : 1 : 1. With more I there will be a separation of iodyrite (hexagonal crystals) on solidification; but with more I it is also possible to have intergrowths of iodyrite and cubic silver haloid.

The known silver haloid minerals may therefore be c'assed under:

Cerargyrite, Ag(Cl, Br.I), holohedral-cubic,
Iodyrite, AgI, hemimorphic-rhombohedral,
Miersite, 4AgI.CuI, tetrahedral-cubic. — L. McI. L.

Hartley, E. G. J.—On the Constitution of Natural Arsenates and Phosphates. *Min. Mag.*, XII., 223, 1900.

Part III.—Plumbogummite and Hitchcockite. Reanalyses of these minerals are recorded.

Hitchcockite from Canton Mine, Georgia, and the mineral from Cumberland, England (formerly mistaken for a zinc silicate) are probably identical, having the formula:

$$2PbCO_3.Pb_3(PO_4)_2 + 6[AlPO_4.2Al(OH)_3.H_2O].$$

Plumbogummite from Huelgoat evidently consists of a somewhat impure mixture of pyromorphite with hitchcockite.

Part IV., p. 234.—*Beudantite* formula:

$$3(Pb, Cu)SO_4.2Fe(P, As)O_4.6Fe(OH)_3.$$

Analysis made on carefully purified material, but locality uncertain.

L. McI. L.

Prior, G. T.—Hamlinite, Florencite, Plumbogummite (Hitchcockite), Beudantite and Svanbergite, as members of a natural group of minerals. *Min. Mag.*, XII., 249, 1900.

Author suggests the following relations:

	Formula.	Crystal. System.	rr′	Axial Ratio.
Hamlinite	$2SrO.3Al_2O_3.2P_2O_5.7H_2O$	Rhomb.	87°2′	$c = 1.1353$
Svanbergite	$2SrO.3Al_2O_3.P_2O_5.2SO_3.6H_2O$	"	89°25′	$c = 1.2063$
Plumbogummite	$2PbO.3Al_2O_3.2P_2O_5.7H_2O$	"	——	——
Beudantite	$2PbO.3Fe_2O_3.P_2O_5.2SO_3.6H_2O$	"	88°42′	$c = 1.1842$
Florencite	$Ce_2O_3.3Al_2O_3.2P_2O_5.6H_2O$	"	88°56′	$c = 1.1901$

There can apparently be a replacement of P_2O_5 by $2SO_3$ without materially affecting the crystalline form.

If, however, the hamlinite formula be written:

$$SrHPO_4.AlPO_4.Al_2(OH)_6,$$

as an ortho- instead of a pyro-phosphate, $SrHPO_4$ may be considered as replaced by $PbSO_4$ in beudantite, $SrSO_4$ in svanbergite and $CePO_4$ in florencite.—L. McI. L.

Solley, R. H.—Sulpharsenites of Lead from the Binnenthal.—*Min. Mag.*, XII., 282, 1900.

Recent analyses are recorded of *sartorite* ($PbS + As_2S_3$), *rathite* ($3PbS + 2As_2S_3$) and *jordanite* ($4PbS + As_2S_3$) and also a tabulation of former analyses is given.

A complete crystallographic description of *jordanite* is given, showing 115 forms of which 11 are new and the system is proved to be monoclinic.

Author regards *geocronite* ($4PbS + Sb_2S_3$) as probably isomorphous with *jordanite*, also describes *sartorite* as monoclinic and *rathite* as requiring new crystallographic elements.—L. McI. L.

Foote, H. W. — On the Physical-chemical Relations of Aragonite and Calcite. *Zeit. f. ph. ch.*, XXXIII., p. 740, 1900.

Author concludes that at ordinary temperatures calcite is more stable than aragonite and that the latter forms when the crystallization of the carbonate of lime is rapid, calcite being formed when the crystallization is sufficiently slow. — L. McI. L.

Farrington, Oliver C. — Observations on Indiana Caves. *Publications Field Columbian Museum, Geol. Series*, 1: 247–266, 1901.

In addition to the detailed description and points of geological interest, the following facts of a mineralogical nature are brought out.

The "Pillar of the Constitution," a huge stalagmite, 71 feet in circumference, in the Wyandotte Cave, is chiefly aragonite (G. = 2.82) though some layers of a microgranular non-fibrous structure are calcite.

In the stalactites and stalagmites from Marengo Cave the peripheral portions are found to be fibrous while the central portions are rhombohedral. The author is of the opinion "that such a structure is evidence of a progressive change in the molecular arrangement of the substance toward a more stable condition" and it is suggested that pressure on the internal substance of the stalagmite might have brought about the change to a rhombohedral condition.

The word stagmalite (*στάγμα*, drop; *λίθος*, stone) is proposed as a general term for formations produced by dripping water, thus including in its definition both stalactite and stalagmite.

The calcite crystals which line the walls of a pool in Coan's Cave increase in size toward the bottom. The crystals formed by immersing

strings in tall jars of solutions of a number of salts were found to increase in number and size toward the bottom, a result which points to a great concentration of solutions at the bottom, a principle already established by Ludwig and Soret. — A. F. R.

Termier, P. — Sur une association d'epidote et de zoisite et sur les rapports cristallographiques de ces espèces minérales. *Bull. Soc. Min.*, XXIII., 50, 1900.

The association of epidote and zoisite *a*, at Mont Pelvas, follows a geometric law.

Epidote, zoisite *a* and zoisite *β* are regarded as trimorphic, with the "net-work" structure of epidote almost exactly orthorhombic, while that of zoisite *a* and zoisite *β* is pseudo-orthorhombic, although the "compound particles" are triclinic. Due to the repeated twinning of the zoisites the external forms appear orthorhombic.— L. McI. L.

INDIVIDUAL SPECIES.

Anapaïte. — Sachs. — *Sitz. der k. Akad. der Wiss.*, Berlin, Jan., 1902.

Triclinic, with crystals elongated parallel to vertical axis; found isolated or in groups of radiating bundles. Color, greenish; transparent; H. = 3–4; G. = 2 81.

Analysis:

FeO	CaO	P_2O_5	H_2O
18.07	27.77	35.51	18.47 = 99.82, yielding

formula $FeCa_2(PO_4)_2 + 4H_2O$; closely allied to that of messelite. Soluble slowly in cold hydrochloric acid. Found in the iron mines of Scheljesni Rog, near Anapa on the Black Sea.— L. McI. L.

A. Lacroix.— Sur un aréniate d'alumine de la mine de la Garonne. *Bull. Soc. Min.*, 24, 27, 1901.

Occurs as a whitish-green fibrous-lamellar crust on quartzose gangue; the surface of the crust showing bright, minute faces. Analysis (W. Flight) yields formula:

$$(Al.\ Fe)\ AsO_4\ .2\ (Al.\ Fe)\ (OH)_8\ .5H_2O.$$

Shows close analogy to liskeardite.— L. McI. L.

Baumhauerite.— R. H. Solly.— Part III. Baumhauerite a new mineral; and Dufrenoysite, *Min. Mag.*, 13, 151, 1902.

Analysis (Jackson) yields formula $4PbS\ .\ 3As_2S_3$. G = 5.329. Monoclinic; $a : b : c = 1.136817 : 1 : 0.947163$; $\beta = 82°42¾'$; 95 forms observed. Crystals rhombic or tabular [parallel to (010) or (100)] in form.

Found in the Binnenthal and closely resembles dufrenoysite and jordanite, from which it may be distinguished by marked oblique development of zone [100.001] (dufrenoysite) and by absence of twin striations and streak (jordanite). Named after Professor H. Baumhauer, of Freiburg.

Dufrenoysite. — A summary of the literature shows that the mineral is comparatively rare and the crystals of large size. System proved not to be orthorhombic but monoclinic with $\beta = 90°3'1½''$; $a : b : c = 0.650987 : 1 : 0.612576$. A crystallographic study with 99 forms are recorded. L. M. I. L.

Bavenite. — Artini. — *Atti. d. r. Acc. dei. Lincei*, 14 Sept, 1901, p. 139.

A white, radiating, fibrous, zeolitic-like mineral, occurring in the pegmatite of Baveno.

Monoclinic, but orthorhombic in appearance, due to twinning parallel to (100). Crystals minute, elongated parallel to *c* and flattened parallel to (100). Easy cleavage parallel to (010). H = 5.5.; G. = 2.72.

Analysis:

H_2O	SiO_2	Al_2O_3	CaO	MgO	Na_2O	
2.49	56.93	15.42	24.47	0.12	0.29	= 99.72,

yielding formula $Ca_2Al_2Si_3O_{18} . H_2O$.

The mineral should prove analogous to apophyllite.—L. McI. L.

The mineral should prove analogous to apophyllite.— L. McI. L.

Brunsvigite. — J. Fromme. — *Tscherm. Mittheil.*, 21, 171, 1902.

Name given to a greenish-brown lepdochlorite occurring in narrow fissures in the gabbro at Schmalenberg (Radauthal), always associated with quartz and calcite. Cryptocrystalline, foliated or sphærolitic, with basal clevage; H. = 1 — 2; G = 3.1. Analysis:

SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	
27.88	15.34	1.77	31.92	0.5[illegible]	
CaO	MgO	H_2O	H_2O (hygroscop.)		
0.20	9.52	11.97	0.15		= 99.73,

yielding formula $6SiO_2$, $2Al_2O_3$, 6FeO, 3MgO, $8H_2O$. — L. McI. L.

Ein neues Cadmium-Mineral. — E. Wittich, and B. Neumann. — *Cbl. f. M. G. u. P.*, 18, 549, 1901.

A ten cm. specimen of calamine from Genarutta, near Iglesias consisted principally of calamine entirely without cadmium. A very thin outer layer carried cadmium and on this was a lustrous black coat of cadmium oxide (CdO) which under the lens was seen to consist in part of sharp cubes and cubo-octahedra less than 0.5 mm. on an edge and in part of the same material in powder. No name was given to the new mineral. — A. J. M.

Calaverite. — G. F. Herbert-Smith. — On the remarkable problems presented by the crystalline development of Calaverite. *Min. Mag.*, 13, 1122, 1902.

A remarkable case, it being the first among minerals to apparently call in question the validity of Haüy's law of rationality of intercepts. The author has made an exhaustive crystallographic investigation with his uinque three-circle goniometer and has obtained the fundamental constants and indices of the forms on the supposition that "the symmetry is triclinic, and becomes pseudo-monoclinic owing to twinning about an axis parallel to the edge of the prism zone."

He has also described four types of twin crystals and makes the following summary:

Morphologically the mineral appears to crystallize in the monoclinic system (see also determination by Penfield and Ford), although with exceedingly complex indices.

The faces lie in zones, but these cannot be assigned to a single, "space-lattice"

The assumption may be made that there may be, making up the structure of the crystal, five distinct "lattices" which are incongruent but not independent. — L. McI. L.

S. L. Penfield and W. E. Ford. — On Calaverite. *Am. Jour. Sci.*, iv., 12, 225, 1901.

A crystallographic study, with special consideration of the zonal relations.

Authors tentatively assume system to be monoclinic, although many of the indices are very complicated. The indices are much simplified by G. F. Herbert-Smith's assumption (based on measurements with the three-circle goniometer) that the mineral is "triclinic, but pseudo-monoclinic owing to twinning about an axis parallel to the prismatic zone."

Calaverite and sylvanite are closely related crystallographically (assuming the system to be monoclinic) and chemically.

Calaverite differs from sylvanite in having no good clino-pinacoid cleavage and by having different forms, usually with complex indices, and by conforming to formula $AuTe_2$, sylvanite having formula $AuAgTe_4$.

Authors regard mineral as a distinct species with silver-white color (not bronze-yellow according to Genth); and recommend for distinction from sylvanite a qualitative test for presence or absence of much silver, by treating with conc. nitric acid and then precipitating AgCl from the clear decanted solution with hydrochloric acid.—L. McI. L.

Calcite.—A. F. Rogers.—Mineralogical Notes, No. 2. *Am. Jour. Sci.*, iv., 12. 42, 1901.

Among other notes author mentions new forms for *calcite*, x: $(49.41.\bar{9}\bar{0}.8)$ on a crystal from Colorado and $\chi(5.5.\bar{1}\bar{0}.1)$, pyramid of second order, on a crystal from Frizington.

A new tetragonal trisoctrahedron $\rho(13.1.1)$ is also mentioned as occurring on *galena* from an unknown locality.—L. McI. L.

Carnotite.—W. F. Hillebrand and F. L. Ransome.—On Carnotite and associated Vanadiferous Minerals in Western Colorado. *Am. Jour. Sci.* iv., 10, 120, 1900.

"The body called carnotite is probably a mixture of minerals of which analysis fails to reveal the exact nature." Doubt is cast on the simple formula $2U_2O_8, V_2O_5, K_2O, 3H_2O$, deduced by Friedel and Cumenge. The deposits of carnotite are superficial and of recent origin.

The green cementing material of certain sandstones, found only near Placerville, is an alumino-vanadio-potassium silicate resembling roscoelite.—L. McI. L.

Ceruleite.—H. Dufet. — Sur une nouvelle espèce minérale, la céruléite. *Bull. Soc. Minn.*, 23, 147, 1900.

Blue color, occurs as a clay-like mass of extremely small rod-like crystals, G.= 2.803, Sol. in HCl.

Analysis:	As_2O_5	Al_2O_3	CuO	H_2O	
	34.56	31.26	11.80	22.32	= 99.94,

yielding formula $CuO.2Al_2O_3.As_2O_6 + 8H_2O$.

Found at Emma Luisa mine, Huanco, Prov. Taltal, Chili, accompanied by a white clay.—L. McI. L.

Chalmersite. — Hussak. — *Centr. f. Min.*, p. 69, 1902. Formerly de-

scribed as millerite. Occurs with quartz, dolomite, pyrrhotite, etc., at Morro Velho, Minas Geraes. Orthorhombic, with crystals twinned as in chalcocite. Crystals elongated, parallel to vertical axis, yellow-bronze in color and magnetic; H. = 3.5; G. = 4.68. Composition: Fe 46.95, Cu 17.04, S 35.90, yielding formula $CuFe_8S_4 = Cu_2Fe_6S_8 = \dot{C}u_2\ddot{S} . Fe_6S_7$, ; suggesting an isomorphous mixture of chalcocite (Cu_2S) and pyrrhotite (Fe_6S_7).—L. McI. L.

Chlorophæite. — Zambonini, F. — Ueber ein merkwürdiges Mineral von Casal Brunori bei Rom. *Cbl. f. M. G. u. P.*, 1901, No. 13, 397.

A greenish-yellow, woolly mineral found in the hollows of the lava, very rare and suggesting a pale variety of breislakite, but differing in color, cleavage and in composition, agreeing closely with *chlorophæite*, to which it is referred.—A. J. M.

Cliftonite. — J. M. Davison. — Internal structure of Cliftonite. *Am. Jour. Sci.*, iv., 13, 467, 1902.

Minute cubo-octahedral crystals found on dissolving a troilite nodule from the Smithville iron. The internal structure proves that cliftonite is not a pseudomorph after pyrite; but it is not so clear that diamond has here been changed to graphite. Author suggests that it may be possible that the carbon under certain circumstances takes the graphitic condition with isometric form.—L. McI. L.

Columbite Group. — L. Goodwin and W. G. Miller. — New mineral of the columbite group. *Jour. Fed. Canada Min. Inst.*, III., p. 151, 1898.

Analysis:

$(Na, Ta)_2O_5$	SnO_2	FeO	MnO	CuO	$(Ce, Di_2, Y)_2$	
75.75	0.92	11.14	10.22	0.03	2.00	= 100

Found in pegmatite with beryl, tourmaline, etc., at Lyndoch, Renfrew Co., Ontario.

Coolgardite. — Ad. Carnot, — Sur les tellurures d'or et d'argent de la région de Kalgoorlie, Australie occidentale. *Bull. Soc. Min.*, 24, 273, 1901.

Analyses given of fragments of ores from this locality, sent on for the exposition of 1900. Author proposes name *Coolgardite* for the mineral from Great Boulder with formula $(Au, Ag, Hg)_2Te_3$.—L. McI. L.

Corundum. — G. Melczer. — Ueber einiger krystallographische Constanten des Korund. *Zeit. f. Kryst.*, 35, 567–581, 1902.

A study of symmetry, axial ratios and indices of refraction on 150 Burmese crystals, a suite of Fremy's artificial crystals and three Ceylon crystals. *Optically Uniaxial.* — In artificial none were biaxial, of fifty natural only six gave biaxial figure, and five of these showed twin lamellæ, when the twinned portion was covered the figure was uniaxial. *Scalenohedal trigonal.* — Measurement, natural etchings, absence of tetrahedral forms and of pyro-electricity all indicate this class. *Prevailing forms.* — Burmese crystals: *c* 0001, *r* $10\bar{1}1$, *n* $22\bar{4}3$, *a* $11\bar{2}0$, often occur alone or with them one or more of *w* $11\bar{2}1$, *v* $44\bar{8}3$ and $50\bar{5}2$. Fremy crystals: show *c*, *r*, *n*, and also $50\bar{5}2$, $20\bar{2}7$ and $07\bar{7}6$, new forms The Descloizeaux form $11\bar{2}3$ was not observed. Axial relation recalculated

$c = 1.3652$. *Indices of refraction.* Increase notably as red color darkens. Blue and white are in the middle. The double refraction is essentially constant. Used prism method and angle between base and opposite rhombohedral face and calculated by Liebisch formulæ. For yellow light used mixture of NaCl and Na_2SO_4 and Laspeyres lamp in direction of length of collimator. Also used knee-like Riedel form of Geissler tube.—A. J. M.

Crocoite. — R. G. Van Name. — On Crystals of Crocoite from Tasmania. *Am. Jour. Sci.*, iv., 13, 339, 1902.

Crystals show two distinct types of development: One habit showing remarkable elongation of the prismatic faces with nearly square cross-section, differing from that illustrated by Palache from this locality. The other habit, the more general one, showing small short prisms, chiefly terminated by simple pyramids.

A complete crystallographic description is given, and a new clinodome *j* (032) recorded.

These very beautiful, bright crystals were found in a mixture of cellular limonite and wad near Dundas.—L. McI. L.

Diamond. — W. H. Hobbs. — Diamond Field of the Great Lakes. *Jour. Geol.*, 7, 375, 1899.

Seventeen diamonds (½–21¼ carats) have been found since 1883 in glacial deposits principally in Wisconsin. Considering the glacial drift, etc., it is probable that the diamonds came from somewhere near James Bay or Hudson Bay. The stones are colorless or greenish or yellowish. — L. McI. L.

Esmeraldite. — A. S. Eakle. — *Univer. Calif. Bull. Geol.*, II., 315, 1901.

A hydrous iron sesquioxide, occurring in coal-black, pod-shaped masses, surrounded by yellowish-brown earthy material, from Esmeralda Co., Nev.

Luster, vitreous; translucent on thin edge; brittle, with conchoidal fracture and yellowish-brown streak; H. = 2.5; G. = 2.578.

Analysis (Schaller):

Fe_2O_3	H_2O (110°)	H_2O (over 110°)	Al_2O_3
56.14	15.94	10.24	5.77

CaO	P_2O_5	SiO_2	organic
3.35	4.49	2.05	1.37 = 99.35,

which, disregarding impurities, yields formula $Fe_2O_3.4H_2O$.

L. McI. L.

Gypsum. — Mühlhauser, A. — Ueber natürlich geätze Gypskrystalle von Kommern. *Tschermak's Minn. Mitt.*, 20, 367, 1901.

Hackmanite. — L. H. Borgström. — *Geol. Fören. Förhandl.*, 23, 563.

A mineral apparently in the sodalite group, occurring in violet red dodecahedral crystals on the island of Kola. G. = 3.32; H. = 5.

Analysis:

SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	Cl	S	
36.99	31.77	0.17	0.5	25.84	0.16	6.44	0.39	= 101.81

(less for Cl) = 100.17; yielding formula $Na_4(Al(SNa))Al_2(SiO_4)_3$. Soluble in HCl.

Named for Mr. Hackman, who explored the island in 1891.

L. McI. L.

Hydrogöthite.—J. Samojloff.—Ueber Hydrogöthite, ein bestimmtes Eisenoxydhydrate. *Zeit. f. Kryst.*, 35, 273, 1901.

The mineral $3Fe_2O_3$, $4H_2O$ described by Zemyatschensky in 1889 has hitherto been only considered to be a transition stage between göthite and limonite. The writer has however found the mineral in several localities in central Russia and in considerable quantity and great purity in the ore of Trosna (Krapiwna). Streak, tile-red; G. 3.73; H. 4; composed of transparent microscopic needles with one easy cleavage, parallel extinction and strong pleochrism, orange red parallel to their length and yellowish-green normal to this direction.—A. J. M.

Kilbrickenite.—G. T. Prior.—The Identity of Kilbrickenite with Geocronite and Analysis of Miersite, Marshite and Copper Pyrites. *Min. Mag.*, 13, 186, 1902.

Kilbrickenite proved to be identical in all physical characters with geocronite and to conform very closely to the geocronite formula $5PbS.(Sb, As)_2S_3$.

The presence of the same per cent. of As in geocronite from different localities supports D'Achiardi's suggestion that the formula is:

$$5PbS.Sb_2S_3 + 5PbS.As_2S_3.$$

Miersite, analysis shows Ag 38.17, Cu 5.64, I 56.58 = 100.39, yielding very close to formula 4AgI.CuI (Spencer's formula by means of fusion experiments). The formula previously assigned (Dana, Append. I) being Ag_2I_2, G. = 5.640.

Marshite, analysis shows Cu 32.35, Ag 1.19, I 65.85 = 99.39, yielding formula CuI (the Ag probably comes from slight isomorphous admixture of miersite).—L. McI. L.

Lasur-oligoclase.—P. V. Jeremejew.—*Zeit. f. Kryst.*, 33, 493.

A partially altered feldspar, containing numerous inclusions of calcite, occurring near the Baikal Lake and formerly called lasur-feldspar by Nordenskiöld. In crystals and composition approaches very closely to the Vesuvius oligoclase.

Lassallite.— See Ternnerite.

Libollite.—J. P. Gomes.—*Comm. Dir. Trabalh. Geol. Portugal*, III., p. 244.

Asphalt, resembling albertite, from Libollo, prov. Angola. Analysis: C = 74.74, H = 7.83, O = 8.80, N = 1.71, Ash = 6.92. G. = 1.1.

Liveingite.—R. H. Solly.—*Proc. Camb. Phil. Soc.*, 1901, XI., p. 239.

Name given to two crystals, most of the material being used for chemical analysis (by H. Jackson). Pb 47.58, S 24.91, As 26.93, Fe trace = 99.42, yielding very close to formula $5PbS.4As_2S_3$. Monoclinic with pseudo-rhombic habit, resembling rathite and sartorite.—L. McI. L.

Lotrite.—G. Munteanu-Murgoci.—Ueber die Einschlüsse von Granat-Vesuvianfels in dem Serpentin, etc. *Inaug. Dissert. de l'Univers. de Munich*, 1901.

The mineral occurs massive, as an aggregate of very minute grains and

plates, in veins in the chlorite-schists at the contact with the serpentine found in the Lotru valley. G. = 3.23; H. = 7.5. Analysis:

SiO_2	Al_2O_3,Fe_2O_3	FeO	CaO	MgO	H_2O	
38.02	30.90	0.33	23.56	2.80	6.24	= 101.85,

yielding the new formula $4SiO_2$, $2(Al.Fe)_2O_3$, $3(Ca.Mg)O$, $2H_2O$.

L. McI. L.

Lussatite.—F. Slavik.—The probable identity of lussatite and tridymite. *Zeit. f. Kryst.*, 35, 690.

The optical properties and partial solubility in hot carbonate of soda tend to show that lussatite is probably a fibrous variety of tridymite.

Manganosphærite.—K. Busz.—*Neues Jahrb. f. Min.*, 2, 129, 1901.

Name given to a reddish-brown, sphærolitic, manganiferous (oligonite) variety of siderite, occurring with siderite in the cavities of the basalt a the Louise mines near Horhausen, Westerwald. Analysis:

FeO, 36.72; MnO, 24.76; CO_2, 38.34.

L. McI. L.

Marsjatskite.—S. von Fedoroff and W. Nikotin. *Ann. Géol. Minn. Russie*, III., 79, 1899.

A glauconite of a greenish color, containing manganese. Alters easily on exposure. Forms the bulk of the tertiary sandstone of the Marsjatsk forest, Urals.

Melanochalcite.—G. A. Koenig.—On the new species melanochalcite and keweenawite. With notes on some other known species. *Am. Jour. Sci.*, iv., 14, 404, 1902.

Melanochalcite found in hard, spheroidal nodules, in a soft brownish clayey material, in a deep (300 ft.) shaft of the Calumet and Arizona Co., near Bisbee, Arizona.

The mineral forms a thin zone (few mm. thick) of pitchy-black massive material, surrounding the cuprite nucleus and being enclosed by zones of chrysocolla and malachite and finally quartz.

Analysis:

CuO	SiO_2	CO_2	H_2O	ZnO	Fe_2O_3	
76.88	7.80	7.17	7.71	0.41	0.07	= 100.04,

yielding results which might indicate an intimate mixture of copper carbonate, silicate and hydrate, or, as suggested by author, a compound of copper silico-carbonate and copper hydroxide, $Cu_2(Si.C)O_4.Cu(OH)_2$. H. about 4; very brittle; G = 4.141 at 21° C. The material analyzed seemed microscopically to be quite homogeneous and amorphous or isometric.

Keweenawite found at the Mohawk Mine, Mich., with domeykite. It occurs as a pale pinkish-brown, fine granular, brittle aggregate. Tarnishes to a brown-red. H. about 4; G. = 7.681 at 20° C. Three analyses suggest formula $(Cu, Ni, Co)_2As$, while mohawkite is $(Cu, Ni, Co)_3As$.

Analyses of other Mohawkite mine material seem to carry out author's theory that "the higher ratios of these copper arsenides are either mixtures (grain very fine) or they partake of the nature of alloys and hence all ratios are possible."

Pulveriform chalcocite from the Champion Mine also described.

L. McI. L.

Mercuric Iodide. — A. J. Moses. — Mineralogical Notes. *Am. Jour. Sci.*, iv., 12, 98, 1901.

Mercuric iodide from New South Wales. Found as a thin layer of very minute, scarlet, sharp-edged cubes ($\frac{1}{10}$ mm.) on impure limonite from Broken Hill Mines. Composition determined by micro-chemical and blowpipe tests. Not sufficient material for quantitative analysis was obtained, but the mineral certainly does not agree with the description of the Mexican iodide of mercury, coccinite, occurring in acute rhombic pyramids.

New forms on *atacamite* crystals from Chili. These specimens from Brilladora Mine are interesting chiefly on account of the well-formed, doubly terminated crystals of short prismatic habit with dome terminations. The Goldschmidt coördinates are recorded.

Realgar crystals from Snohomish Co., Wash., are found in long prismatic forms which were measured and described, the first of such crystals to be found in America.—L. McI. L.

Molybdophyllite.—G. Flink.—Abst. in *Am. Jour. Sci.*, iv., 12, 469, 1901.

A new lead silicate found in irregular, micaceous-like masses in the granular limestone at Långban, Sweden. Colorless, with vitreous lustre, but pearly on the perfect basal cleavage. Hexagonal; H. = 3–4, G. = 4.717. Analysis:

SiO_2	PbO	MgO	Al_2O_3	Na_2O	K_2O	H_2O	
18.15	61.09	11.71	0.46	0.82	0.69	6.32	= 99.24;

yielding formula $R_2SiO_4 + H_2O$.—L. McI. L.

Monazite.—O. A. Derby.—On the Occurrence of Monazite in Iron Ore and in Graphite. *Am. Jour. Sci.*, iv., 13, 211, 1902.

Suggests that the presence or absence of monazite indicates a difference in the mode of origin of the graphitic schists and gneisses or granites.

L. McI. L.

Muschketowite.—S. von Fedoroff and W. Nikotin. *Am. Geol. Min. Russie*, III, 79, 1899.

A pseudomorph of magnetite after hematite, found at Bogoslowsk, Urals.

Natrojarosite.—W. F. Hillebrand and S. L. Penfield.—Some Additions to the Alunite-Jarosite Group of Minerals. *Am. Jour. Sci.*, iv., 14, 211, 1902.

Natrojarosite from Soda Springs Valley, Nevada, found as a yellowish-brown, glistening powder made up of minute rhombohedral crystals with base largely developed. Analysis shows the material to have the same composition as jarosite, with substitution of soda for potash.

Plumbojarosite from Cook's Peak, New Mexico, found as a dark brown, glistening powder (of minute rhombohedral flattened crystals) or as loosely cohering masses. Analysis indicates that mineral may be regarded as a jarosite with substitution of lead for the alkalies; the first case of such isomorphism known to the authors. This isomorphism is probably explained by the *mass effect* of the other constituents, the alkalies and lead playing a very small rôle in the complex chemical molecules.—L. McI. L.

Pseudomésolite.—A. N. Winchell.—Etude min. et pétrog des roches gabbroïques de l'Etat de Minn. États-Unis, etc.—Thèse Fac. des Sc. de Paris, 1900. Abst. in *Bull. Soc. Min.*, 24, 506, 1901.

The mineral is a zeolite, very close in composition to mesolite, but quite different in its optical properties It is found in the anorthosite of Carlton Peak, Minn.—L. McI. L.

Quartz.—G. Spezia.—Solubilité du quartz dans des solutions de tétraborate de sodium.—*Atti. Acc. Sc. Torino*, 36, 631, 1901.

A sample of quartz, weighing 1.0678 gr., heated under pressure to a temperature of 290°–315°, in a 5 per cent. solution of borax, lost in four days 0.257 gr. At ordinary temperatures and pressures no action was noticed.

These results would tend to show that the borosilicates (as tourmaline, datolite, etc.) are probably formed at high temperatures.—L. McI. L.

Ransatite.—Weibull.—*Geol. För. Forh.*, xx., p. 53.

Mineral described by Igelström (Bull. Soc. Min., xxi) is a manganiferous garnet, containing inclusions of quartz, pyrophyllite, chloritoid, cyanite and hematite.

Rathite.—K. H. Solly.—Sulpharsenites of Lead from the Binnenthal. —Part II., Rathite. *Min. Mag.*, 13, 77, 1901.

Orthorhombic, with $a : b : c = 0.4782 : 1 : 0.5112$.

A new orientation (from that of Baumhauer) chosen so that the well-developed zone becomes prismatic and the cleavage parallel to 010 (corresponding to that of jordanite) instead of parallel 001 (Baumhauer). Five different habits of crystals observed, most of the crystals showing twin striations. Twin planes (074) and (0.15.1), which are forms not developed on the crystals. Sixty-two forms are recorded, of which thirty-seven are new. $3PbS.2As_2S_3$; G. = 5.412–5.421 (Baumhauer 5.32); color, lead-gray to steel-gray; streak, chocolate; fracture, conchoidal; H. = 3.

Found only in the bed of the Lengenbach.—L. McI. L.

Robellazite. — *Bull. Soc. Min.*, XXIII., 17, 1900.

Mentioned by Cumenge as occurring with carnotite in Colorado. Partial analysis shows considerable vanadium and also niobium, tantalum and tungsten with alumina, iron and manganese as bases.

Seligmannite. — Baumhauer. — *Ber. Ak. Berlin*, p. 110, 1901.

A new species from the dolomite of Binnenthal, Switzerland. No analysis; but close identity with bournonite in crystalline form and with sartorite in color, luster and brittleness leads to the conclusion that it is a lead sulpharsenite of this isomorphous group.

Serendibite. — G. J. Prior and A. K. Coomara-Swamy. — *Cent. f. Min., Geol. und Pal.*, 1902, p. 186.

Name given to a blue (very pleochroic) granular mineral, occurring at the contact of granulite and limestone near Gangapiliya. Essentially a borosilicate of Al, Ca and Mg; G. = 3.42; H. = 7. A more complete description will appear in the *Bull. Soc. Minn.* — L. McI. L.

Sperrylite. — H. L. Wells and S. L. Penfield. — On a New Occurrence of Sperrylite. *Am. Jour. Sci.*, iv., 13, 95, 1902.

Found in very minute brilliant crystals in the copper ore (covellite)

from Rambler Mine, fifty miles southwest of Laramie. Platinum varies from .06 to 1.4 oz per ton in this mine. — L. McI. L.

Stannite.—L. J. Spencer. — Crystallized Stannite from Bolivia. *Min. Mag.*, 13, 54, 1901.

The principal crystals investigated were very minute (1–1.5 mm.) and were found by Sir W. Martin Conway (in his Bolivian expedition of 1898), at the San José Mine, Oruro, encrusting arsenopyrite crystals.

Crystallization, scalenohedral-tetragonal, but by twinning pseudo-tetrahedral-cubic. Faces usually striated and rough. Twelve forms recorded. Twinning most interesting and invariably present.

Color, iron-black; lustre bright metallic to sub-adamantine, somewhat like black blende; brittle; H. = 3.5; G. = 4.45.

Analysis (by G. T. Prior) gave (mean):

Cu	Fe	Sn	Sb	Pb	Ag	S
28.56	10.93	25.21	3.71	2.06	0.88	27.83 = 99.18,

yielding (after deducting Sb, Pb, Ag for some admixed andorite) formula Cu_2FeSnS_4.

This formula could be written $CuFeS_2 + CuSnS_2$, showing possible relation to chalcopyrite $CuFeS_2$, with which it has remarkably close crystallographic relations.

Other crystals from Bolivia were examined and proved to be stannite.

L. McI. L.

Stoffertite. — Klein. — *Berl. Akad. Wiss.*, June 13, 1901, p. 712.

Name given to a hydrous phosphate of lime, similar to metabrushite, found on the island of Mona. Monoclinic.

Sulphur. — R. Brauns. —Great stability of some modifications of sulphur. *Cent. f. Min.*, 1902, p. 7.

The orthorhombic form is alone stable at ordinary temperatures; the other forms gradually changing to this. Monoclinic crystals (discovered by Mitscherlich) have however remained unchanged for three years.— L. McI. L.

Synchisite.— G. Flink.— Abst. in *Am. Jour. Sci.*, iv, 12, 469, 1901.

A new mineral, formerly described by Nordenskiöld as parisite. Found at Nararsuk, Greenland, in wax-yellow, acute rhombohedrons. H. = 4.5. G. = 3 902.

Analysis (Mauzelius):

CO_2	ThO_2	Ce_2O_3	$(LaDi)_2O_2$	Y_2O_3
25.99	0.30	21.98	28 67	1.18
Fe_2O_3	CaO	F	H_2O	
0.11	16.63	5.04	2.10 = 102.00;	

yielding formula $CeFCaC_2O_6$. — L. McI. L.

Termierite.—G. Friedel.—Sur la termiérite et la lassallite, deux espéces nouvelles des silicates. *Bull. Soc. Min.*, 24, 4, 1901.

Found with kaolinite and barite at Miramont (the antimony deposits), France.

Termièrite, analysis: SiO_2 78.29, Al_2O_3 15.00, Fe_2O_3 (FeO pt. ?) 4.85, CaO 1.77, MgO 0.47 = 100.38, yielding formula $Al_2O_3.6SiO_2 + 18H_2O$. Occurs in small gray masses with conchoidal fracture.

Lassallite, analysis (on dried material): SiO_2 69.27, Al_2O_3 19.42, Fe_2O_3 0.84, MgO 10.01, CaO 1.30, H_2O 14.22 = 100.84; yielding formula $3MgO.2Al_2O_3.12SiO_2 + 8H_2O$. Occurs in white, asbestus-like fibers.—L. McI. L.

Torbernite.—F. Rinne.—Kupferuranite und seine Entwasserungsprodukte. *Cbl. f. M. G. u. P.*, 1901, No. 20, 618.

The doubt thrown upon the crystalline system of *torbernite* by the investigations of Walker (*Am. J. Sci.*, VI., 41, 1898) lead to a further study of the torbernite of Redruth, Cornwall, as the result of which Rinne claims that for this material the system *is* tetragonal. Also that by loss of water at 60–65 these negative crystals pass into positive tetragonal crystals and by further loss at 100 into a series of orthorhombic compounds similar to autunite in structure.—A. J. M.

Tourmaline.—E. A. Wülfing.—*Program. 3.82 Jahresfeier d. k. Württemb. landwirt. Akad. Hohenheim*, p. 99, 1900.

Discusses *tourmaline* and gives connection between crystallographic constants and chemical composition and also the results of thirty-three best analyses. Previous constants are discussed and new crystallographic, optical and density determinations are given.—L. McI. L.

Turquois.—S. L. Penfield.—On the Chemical Composition of Turquois. *Am. Jour. Sci.*, iv., X., 347, 1900.

The analysis of exceptionally pure and homogeneous material from Crescent mining district, Lincoln County, Nevada, shows that the composition may be expressed as follows:

$$[Al(OH)_2, Fe(OH)_2, Cu(OH),H]_3PO_4$$

The $[Al(OH)_2]$ radical always predominates but is not present in fixed proportion. This does not agree with Clarke's suggestion that the mineral contains iron and copper phosphates as impurities.—L. McI. L.

Valeriite.—J. Petrén.—*Geol. Fören*, XX., p. 183. Name formerly given by Blomstrand to a substance with formula:

$$2CuS, FeS_2 + 2MgO, Fe_2O_3 + 4H_2O.$$

Proved to be now a mixture.

Viellaurite and Torrensite.—A. Lacroix,—Sur les minéraux des gisements manganésifères des Hautes-Pyrénées. *Bull. Soc. Min.*, XXIII., 251, 1900.

The supp sed new minerals *viellaurite* and *torrensite*, of Ville-Aure, described by Lienan, are proved to be simply mixtures of dialogite and tephroite and of dialogite and rhodonite, respectively.—L. McI. L.

Yttrialite.—W. F. Hillebrand,—The composition of Yttrialite with a criticism of the formula assigned to Thalénite. *Am. Jour. Sci.*, iv., 13, 145, 1902.

An elaborate chemical discussion. Author concludes that empirical formula of Hidden and Mackintosh for yttrialite is confirmed, and that the basic formula of Benedicks has no standing, as it rests on error.

This formula of Hidden and Mackintosh is not that of a simple salt of the acid $H_6Si_2O_7$, but the real formula *may* be that of a basic metasilicate $R''R'''_2(R'''O)'_2(SiO_3)_7$.

The thalénite formula proposed by Benedicks is doubtful.—L. McI. L.

Woodbridge School,

FORMERLY

School of Mines Preparatory School.

---

417 Madison Avenue,

Between 48th and 49th Streets, NEW YORK CITY

Twenty-second Year Begins October 1st, 1903.

THE school is well equipped with physical and chemical laboratories, in which the students are required to perform a complete set of experiments illustrative of their recitations in physics and general chemistry. A special laboratory is devoted to qualitative chemical analysis for advanced students.

Five hundred Students of Columbia School of Mines have been instructed in the Woodbridge School. Also a large number have been prepared for Massachusetts Institute of Technology, Stevens Institute, Sheffield Scientific School, Lawrence Scientific School, Troy Polytechnic Institute, Cornell University, and the Classical, Medical, and Law Departments of Harvard, Yale, Columbia and Princeton.

A summer school for students who have failed in June begins August 13th and coaches men for the Fall examinations. All classes are limited to five. College men are coached in Freshman and Sophomore Mathematics and Quantitative Analysis.

An advanced course for older students prepares them to enter the second year class. Last June one of our students received his degree in Electrical Engineering in three years.

VOL. XXIV. No. 3. APRIL, 1903.

THE SCHOOL OF MINES QUARTERLY.

A

JOURNAL OF APPLIED SCIENCE.

BOARD OF EDITORS.

A. J. MOSES, Prof. of Mineralogy.
J. F. KEMP, Prof. of Geology.
R. PEELE, Adj. Prof. of Mining.
A. D. F. HAMLIN, Adj. Prof. of Architecture.
R. E. MAYER, Instructor in Drawing.
E. WALLER, Analytical Chemist.
JOS. STRUTHERS, Ph.D.,
I. H. WOOLSON, Instructor in Mechanical Engineering.
W. H. FREEDMAN, E.E.,
T. H. HARRINGTON, Tutor in Drawing.

Managing Editor, R. E. MAYER,
Business Manager, T. H. HARRINGTON.

CONTENTS:

Radio-Activity and Chemistry. By George F. Barker 267
The Geology of the Cerrillos Hills, New Mexico. By Douglass Wilson Johnson 303
On the Use of Influence Lines in Graphic Statics. By Myron S. Falk 349
The Latest Progress in Shaft Sinking. By Chief Engineer Riemer..... 361
A Rapid Method for the Determination of Arsenic in Arsenopyrite. By J. L. Danziger and W. H. Buckhout 400
Book Reviews..... 405

COLUMBIA UNIVERSITY
NEW YORK CITY.

Registered at the New York Post Office as Second Class Matter.

TWO DOLLARS PER YEAR. FIFTY CENTS PER NUMBER.
All Remittances should be made payable to Order of "The School of Mines Quarterly."

Portland Cement

THE LAWRENCE CEMENT CO.

ESTABLISHED 1832.

ERNEST R. ACKERMAN, President

This Company has manufactured and sold during 70 years upwards of **20,000,000** barrels of Cement; marketing the product in all the principal cities of the United States, Canada, West Indies, Philippines and South America.

The old Custom House on Wall Street, built in 1835–37, and the new Custom House on Bowling Green, now under construction, were built with cement sold by this Company.

Used on the Old and on the New Stock Exchange in New York City, on the Brooklyn Bridge and New East River Bridge, and on the new Chamber of Commerce Building.

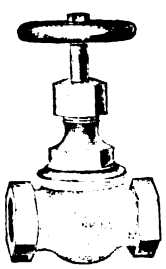
Detailed list of important Government Work Reservoir Dams, Sidewalks, Fortifications, Bridges, Municipal Buildings and Railroad Work where "DRAGON" has been used, furnished on application.

DRAGON PORTLAND CEMENT Stands the Highest Requirements of Architects, Engineers and Builders.

SALES OFFICES:

NEW YORK, No. 1 Broadway. 15th and Market Sts., PHILA.

JENKINS BROTHERS' VALVES



Perfectly tight under all pressures of steam oils, or acids. Warranted to give satisfaction under the worst conditions.

Received the Highest Award **GOLD MEDAL** At the Pan-American Exposition.

Insist on having the genuine stamped with Trade Mark.

Jenkins Brothers, New York, Boston, Philadelphia, Chicago, London.

THE

SCHOOL OF MINES QUARTERLY.

VOL. XXIV. APRIL, 1903. NO. 3.

RADIO-ACTIVITY AND CHEMISTRY.*

BY GEORGE F. BARKER.

GENTLEMEN OF THE CHEMICAL SOCIETY:

The words radiate and radiation are familiar to us in ordinary life. Railways are said to radiate from a junction, and streets to radiate from a common point of intersection. Meteors appear to stream out from a point in the heavens which is called the radiant point. The sun radiates energy to us; the apparatus by which our houses are warmed with steam heat is called a radiator, and rays of sound reach our ears from all musical instruments. The word ray, however, represents only direction; a light ray, a heat ray or a sound ray is not light, heat or sound, but represents only the direction along which these agencies travel. A source from which rays are emitted is said to be a radio-active source, and a radio-active body is a body which is active in emitting rays. The property of thus emitting rays is called radio-activity.

Within the past few years a surprising progress has taken place in the discovery of new varieties of rays; and the phenomena connected with these rays have had material influence in modifying the views generally received, not only on the subject of radiation, but particularly upon the constitution of matter. We can study these phenomena by means of the electric discharge perhaps better

* An address delivered by Professor George F. Barker, LL.D., of the University of Pennsylvania, before the Chemical Society of Columbia University in Havemeyer Hall, March 19, 1903.

than in any other way. When, for example, an electric spark passes through the air, its path, as you see, is a zigzag line five or six inches in length. If, however, the air through which the discharge passes is rarefied, as is the case in the tubes before us, the spark will pass through five or six feet of air instead of a few inches. Moreover, you will observe that the light in these tubes is purplish in color, determined by the character of the gas which they contain; being crimson in the case of hydrogen, flame-red in that of neon, and purple-red with nitrogen. These tubes were first made by Geissler, of Bonn, and therefore are known as

FIG. 1. Sir William Crookes.

Geissler tubes. The exhaustion in them is such as to support a column of mercury somewhat less than a millimeter high; representing therefore a pressure of about a thousandth of an atmosphere.

In 1879 Sir William Crookes made an elaborate investigation of the phenomena produced by the electric discharge in much higher vacua.* The tubes devised by him are known as Crookes tubes. In the one before you you notice that the electric discharge produces a greenish color and that the path of the discharge itself is no longer visible. The exhaustion in these Crookes tubes is only one thousandth of that in the Geissler tubes, or is about a millionth of an atmosphere.

* Crookes, *Phil. Trans.*, CLXX., 135, 641, 1879; *Nature*, XX., 419, 436, 1879.

In the Geissler tube (Fig. 2) the discharge visibly passes between the anode and the kathode,* the one terminal being of as much importance apparently as the other.† In the Crookes tube, however (Fig. 3), the discharge is entirely independent of the anode and appears to proceed from the kathode alone. Moreover, you will notice that in the Crookes globe the luminous effect upon the glass is directly opposite to the kathode, so that the rays proceeding from the kathode move in straight lines and strike upon the glass exactly opposite the electrode. For this reason these rays

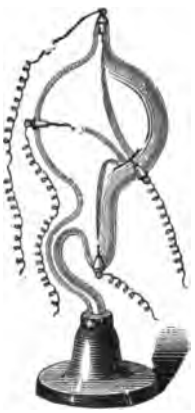


FIG. 2.

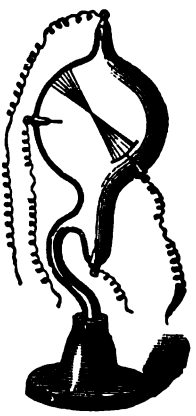


FIG. 3.

thus produced in this very high vacuum are sometimes called kathode rays. In further proof of the fact that these kathode rays pass in straight lines, Sir William Crookes has devised the beautiful tube which is now before you (Fig. 4). Between the kathode and the glass at the opposite end of the tube is a little Maltese cross made of metal. When the discharge passes, the Maltese cross intercepts the kathode rays and their shadow is produced upon the glass, this shadow being dark on a green ground. The production of light in this way without any considerable heat was called luminescence by E. Wiedemann and the glass is said to luminesce under the action of the kathode rays. The color of this luminescence depends, not upon the gaseous contents of the tube, but upon the solid material upon which the rays impinge. The Crookes

* The word electrode is used to signify a conducting terminal by which the discharge is carried into or out of the tube; the one by which the current enters the tube being called the anode, and the one by which it leaves it the kathode.

† In Figs. 2 and 3 the kathode is on the right-hand side.

tubes we have thus far used are made of German glass and the luminescence produced is greenish. Here is a tube which is made of flint glass and the luminescence is a beautiful blue. Within the tube which I now show you is a piece of ordinary coral. When the Crookes rays strike this coral a brilliant reddish or purplish-blue luminescence is produced which is very intense. Next to the diamond, the ruby luminesces most powerfully. Fig. 5 shows the ruby tube of Crookes.

Here again is an interesting tube devised by Sir William Crookes

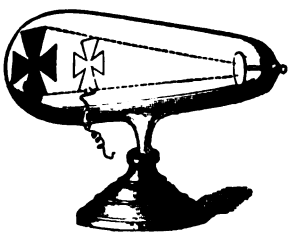


FIG. 4.

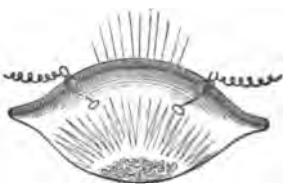


FIG. 5.

for showing the path of the rays (Fig. 6). It contains a strip of mica, on one face of which is placed a luminescent powder. Through a narrow slit in a disk of mica at the left-hand end of the strip and perpendicular to it, the Crookes rays are made to pass, and as they move over the mica they cause a luminescent streak on it where they impinge. By means of this ingenious contrivance we can study one of the most remarkable properties of these rays. If I bring beneath this tube an ordinary steel magnet you will observe that the ray is deviated either downward or upward according to the polarity of the magnet. In the same way, by bringing

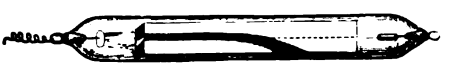


FIG. 6.

the magnet near to the Maltese cross tube when in action we may deviate the Crookes rays in that tube, causing the shadow to move about over the end of the tube. Hence it is obvious that the Crookes rays cannot be light rays, since they are deviated by a magnetic field. Here is a second similar tube (Fig. 7) in which there are two kathodes and also two parallel openings in the mica disc at the lower end of the mica strip; so that when a discharge takes place through either of them a straight line of light is pro-

duced along the strip. When the discharge takes place through both simultaneously, however, the two lines of light are deviated away from each other, passing toward the edges of the strip to the right and left as is shown by the dotted lines in the figure. Inasmuch as two similarly electrified bodies repel one another, the repulsion of these two streams indicates the deviation of the Crookes rays by an electrical field as the first tube did by a magnetic one.

Further, these Crookes rays carry a good deal of energy with them. If the kathode be made concave, inasmuch as the rays are

FIG. 7.

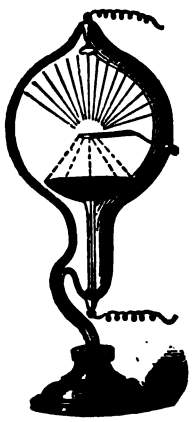


FIG. 8. *

shot out at right angles to the surface, they will converge to a common focus; and now, if a thin plate of platinum is placed at this focus it will be raised to redness, as the tube which is now in action before you clearly shows (Fig. 8). If the current is sufficiently strong, it may even be melted; as Sir Wm. Crookes proved by fusing platinum-iridium in this way. The amount of this energy has been calculated by Perrin, who concludes that a kilogram of these corpuscles, on impact, would raise to the boiling point in one second the waters of a lake 1,000 hectares (2,500 acres) in area and 5 meters (16.4 feet) deep.

And now, what is the nature of these Crookes rays? Sir William Crookes himself was of the opinion that they consist of the material particles of the residual gas, which being negatively elec-

* For the loan of these Crookes tube cuts we are indebted to Queen & Co.

trified at the surface of the kathode are repelled by it and driven away with a high velocity. In proof of his hypothesis he devised a variety of tubes beautifully showing this mechanical action. Here is a Crookes tube, for example, which contains a little windmill with its vanes inclined to the axis about which it turns. Above it is the kathode and when the rays are shot out from this electrode they strike the vanes and drive the little windmill around with great

FIG. 9.

speed. To make the rotation more apparent you notice that the vanes are colored with luminescent materials showing brilliant red and blue colors when the rays strike them. In Crookes railway tube (Fig. 9) the fly rolls along a pair of glass rails. By making the proper terminal the kathode it may be driven in either direction. In the tube now shown (Fig. 10) the vanes are parallel with the axis like a radiometer and are covered on one side with

FIG. 10.

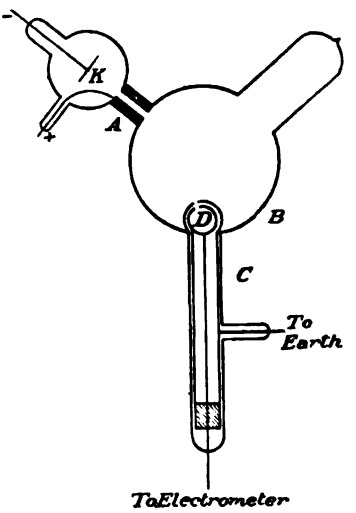


FIG. 11.

mica. So that if we make these vanes the kathode, the discharge of the electrified particles from their surfaces causes a revolution of the fly by reaction. Since the kathode is the negative electrode the particles which have come in contact with it and been thereby driven off must be negatively electrified.

In 1895 Perrin* proved the fact, and two years later J. J. Thomson confirmed it,† that the Crookes rays consist of streams of negatively electrified material particles. A diagram of the apparatus by which Thomson obtained his results is now before you on the screen (Fig. 11). On the left side, at the upper end of the diagram, is a Crookes tube, K being the kathode and A the anode. The rays from the kathode, being driven out in straight lines, impinge upon the wall of the larger globe at the point B. At the lower side of this large globe is a tube containing a metal ball D, which by means of a wire is connected with an electrometer. Outside of this ball is a thin metallic casing C terminating in a sphere above, surrounding the ball and connected to earth. By this external tube the ball is screened from all outside electric influence. The ball itself and its envelope are seen to be pierced with openings opposite one another; and now, if by means of a magnet, the rays be deviated so that instead of striking the glass at the point B they strike the openings, they penetrate the ball and give up their charge to it. When in operation this apparatus shows that the electrometer becomes negatively electrified; a negative charge having been imparted to the ball by the contact of the negatively electrified particles.

Moreover, Thomson continued his investigations much further. In fact, he succeeded in actually measuring the mass, the charge and the velocity of these negatively electrified particles constituting the Crookes rays.

We have seen that these rays are deflected by both a magnetic and an electric field. Now, we know that if the lines of force of the magnetic field are perpendicular to the direction of motion of a particle, the particle will experience a force which is perpendicular to both these directions and whose value is equal to Hev. Many years ago, as Thomson points out, Sir George Stokes showed that when the particles move at right angles to the direction of the field they describe circles whose radius ρ is equal to mv/He, in which m represents the mass of the particle, v its velocity, e its electric charge and H the strength of the field. Whence $H\rho = mv/e$. The character of the trajectory as altered by a magnet is now on the screen (Fig 12). The rays from the kathode K pass through a slit at B and strike the glass at C. Under the action of

* Perrin, *Comptes Rendus*, cxxi., 1130, 1895.

† J. J. Thomson, *Phil. Mag.*, V., xliv., 293, 1897.

a magnetic field whose lines are perpendicular to the paper, these rays are deflected to *D*, the trajectory being now the arc of a circle. Suppose now that we use an electric field and a magnetic field conjointly at right angles to each other and to the direction of motion of the particles; and further that we make the electric force *Fe* balance the magnetic force *Hev*. We then shall have the electric force $Fe = Hev$, from which $v = F/H$; or, in other words, the speed of the particles is the ratio of the intensity of the two fields. Substituting the value of v thus obtained in Sir George Stokes' formula, we obtain the value of m/e; *i. e.*, the ratio of the

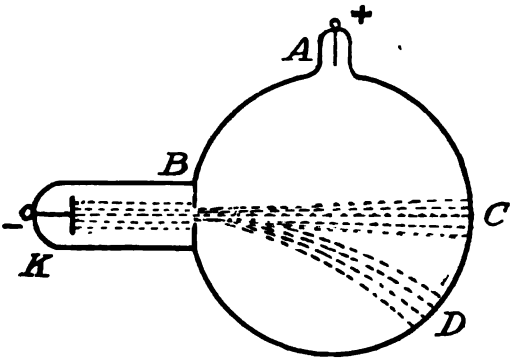


FIG. 12.

mass of the particle to its electric charge. Professor Thomson found for the value of m/e, 10^{-7}; so that when e is equal to 1, m is represented by 10^{-7}. As these values are in C.G.S. units, the mass of the particles required to carry unit charge under these conditions is $\frac{1}{10000000}$ of a gram or $\frac{1}{10000}$ of a milligram.*

Inasmuch as Thomson also proved that the electric charge on a particle in the case of gaseous electrolysis is the same as that on a hydrogen atom in liquid electrolysis, namely, 1.13×10^{-20} E.M.U., and since the mass of hydrogen required to carry a unit charge in the case of ordinary electrolysis is $\frac{1}{10}$ of a milligram, it follows that the mass of kathode particles required to carry a unit charge (since this mass is $\frac{1}{10000}$ of a milligram) can be only $\frac{1}{1000}$ as great. In other words, that the mass of each of these particles constituting the kathode rays is only $\frac{1}{1000}$ of the mass of a hydrogen atom. Now, as the received value of the mass of a hydrogen atom is $2.3 \times$

* J. J. Thomson, *Phil. Mag.*, V., xlviii., 547, 1899; *Proc. Roy. Inst.*, xvi., 574, 1901.

10^{-21}, the mass of a kathode particle must be $\frac{1}{1000}$ of this, or 2.3×10^{-24} milligram.

In Thomson's experiments the speed of the particles was determined to be from 2.2 to 3.6×10^{9} centimeters per second. As the speed of light is 3×10^{10} centimeters per second, the particles constituting the kathode rays in Thomson's experiments had a velocity of about one tenth that of light. Since, however, the trajectory and therefore the velocity depends upon the degree of exhaustion

FIG. 13. Professor J. J. Thomson.

in the tube, it varies somewhat in different experiments, the highest value thus far obtained being 70,000 miles a second, or about two fifths the speed of light. The variation of the trajectory with the exhaustion is readily shown by the tube now before you (Fig. 14). It is similar to the deflection tube just shown except that

FIG. 14.

a small tube containing potassium hydrate is placed at one end. If, at first, the trajectory is represented by the lesser curvature it becomes greater on lowering the vacuum by heating the little tube, thereby setting free moisture.

Moreover Thomson has shown that the ratio of the mass of a particle to its electric charge is entirely independent both of the

nature of the gas and of that of the electrodes; and hence that these particles constitute an entirely new kind of matter hitherto unknown. Since the phenomena in many respects so strongly suggest the Newtonian corpuscular theory, Professor Thomson calls these particles "corpuscles." They constitute invariable constituents of all material atoms and molecules. Indeed, Professor Thomson has gone so far as to suggest that they constitute negative electricity; thus implying a return to the electric single fluid theory of Franklin.*

The question now arises, can these or similar rays be obtained outside of this highly exhausted tube? In 1893 Professor Lenard† replaced a portion of the glass wall of the tube opposite the kathode, with a very thin plate of aluminum and thus obtained outside the tube rays very analogous to the Crookes rays. By the

FIG. 15. Professor W. C. Roentgen.§

kindness of Mr. Nikola Tesla, I show you here some Lenard tubes made by him, together with several radiographs taken with them. The following year Professor Roentgen,‡ of Würzburg, discovered rays which had peculiar properties, outside of the ordinary walls of a Crookes tube. There was lying upon his table, near the tube with which he was experimenting, a piece of cardboard

* J. J. Thomson, *Harper's Magazine*, ciii., 564, September, 1901.

† Lenard, *Ann. Phys. Chem.*, li., 225, 1894; lvi., 255, 1895.

‡ Roentgen, *Nature*, liii., 274, 1896; *Ann. Phys. Chem.*, LXIV., 1, 12, 18, 1898.

§ This cut, and also that of Sir Wm. Crookes, were taken by permission of the Macmillan Company, from S. P. Thompson's book, "Light, Visible and Invisible."

covered with a familiar luminescent material known as the platino-cyanide of barium. He observed that when the tube was in action this card luminesced strongly. Moreover, these new rays had a remarkable penetrating power. They passed through a book of a thousand printed pages; through a double pack of cards; through boards two or three centimeters thick; through tin foil and aluminum foil; through hard rubber; through silver, copper, platinum, gold and lead, which he found to be transparent to them in this order. A lead plate 1.5 millimeters thick, however, was quite opaque to them.

In the Crookes tube now before you (Fig. 16) you will observe that a platinum plate *A* is placed at an angle of 45° to the mean direction of the Crookes rays, which are converged upon it from

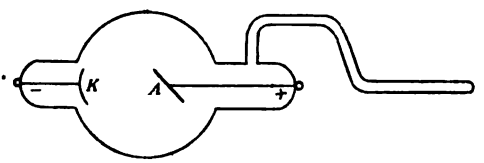


FIG. 16.

a concave kathode *K*, in the focus of which is the plate. At the point of impact the new rays, which are now known as Roentgen rays, originate, and hence the point of impact is their source. They move in straight lines; they produce luminescence in various materials; they affect the photographic plate; they have an extraordinary penetrating power, and they can ionize gases and so render them conducting. If, for example, I place a barium-platino-cyanide screen in front of the tube, you will observe that when the tube is operating the screen lights up brilliantly under the action of these rays; and this notwithstanding the fact that a black enameled cloth impervious to light is placed between it and the tube.

I have here a number of sheets of metal arranged in this order: platinum, lead, silver, copper, iron, zinc, aluminum, the order being that of their densities, platinum having a density of 21.5 and aluminum one of 2.5. I place each of these sheets successively between the Crookes tube and the luminescent screen. When placed in front of the screen you notice that they are all perfectly opaque to the luminescent light which the screen itself emits, but that when placed behind the screen the absorptive effect produced

diminishes regularly, and in approximately the same order as the density diminishes.* Through this rather thin sheet of platinum, for example, no Roentgen rays are transmitted and the field is dark. The lead sheet being much thicker also practically stops the rays. The screen begins to luminesce when the silver plate is introduced, the luminescence increasing steadily until with the aluminum scarcely any difference can be noticed when the metallic sheet is introduced. Hence substances like the metals, which are opaque to light, are penetrable by Roentgen rays. Conversely, we may show in this way also the non-transparency to the Roentgen rays of substances which are perfectly transparent to light. Thus you observe that ordinary window glass, which is perfectly transparent to light, is only semi-transparent to the Roentgen rays; and wood, which is perfectly opaque to light, is perfectly transparent to these rays; as is also celluloid, and to almost the same degree, ebonite.

This remarkable penetrating power of the Roentgen rays, so entirely unlike that possessed by light, may also be well shown by making use of the ordinary photographic plate for this purpose; since such plates are sensitive to these rays. Effects so produced are known as radiographs, to distinguish them from the effects produced by light which are called photographs. I have the pleasure of showing you here Roentgen-ray radiographs of various sorts. Here is an aluminum medallion of the great chemist Woehler, the discoverer of this metal. The original medallion was in copper, and when aluminum was made commercial by Mr. Hall's discovery, Dr. Chandler suggested the reproduction of this medallion in aluminum in order to connect the name of his old teacher with one of Woehler's most important discoveries. Placing this medallion upon an ordinary photographic plate, protected from the action of ordinary light, by layers of black and orange-colored paper Roentgen rays were allowed to fall upon the medallion for ten minutes. The radiograph shows the profile of Woehler perfectly, in consequence of the varying transparency of its different parts in virtue of their different thicknesses. Here is a print from the original plate, mounted side by side with an ordinary photograph of the same medallion, showing the relation of the radiograph to the photograph. I have here a second radiograph of the same general character, but taken through a different metal. It was made from a copper

* The plates were not exactly of the same thickness.

medallion of Professor Henry Draper and was taken from the original design made by Chaplain of Paris, for the gold medal now given by the National Academy of Sciences for investigations in astronomical physics, the fund having been donated for this purpose by Mrs. Draper. The detail of this radiograph is remarkable.

Again, the photographic method may also be used to illustrate the difference in the penetrability to Roentgen rays of what are ordinarily called transparent bodies. Here is a plate on which were placed the six transparent minerals: rock-salt, fluorspar, calcite, mica, quartz and selenite. The radiograph shows that they are all more or less opaque to the Roentgen rays, the first three being perfectly so. Moreover, on the same plate, lower down, we have crown glass, unannealed glass, flint glass, didymium glass and uranium glass, and also paraffin. The paraffin is seen to be perfectly transparent; while the flint glass is very opaque, the unannealed glass more transparent and the crown glass still more so; the others being intermediate.

It is interesting to observe the transmissibility of these rays in the case of precious stones. Here is a radiographic plate on which were placed four imitation diamonds, three genuine ones, three quartz crystals, a cut beryl and a diamond ring. Throwing an image of this plate on the screen you perceive that the imitation diamonds are perfectly opaque, no Roentgen rays being transmitted through them and the plate beneath them being, therefore, unaffected; while the diamonds are equally transparent, the plate being darkened under them as though they were not there. Quartz and the beryl are intermediate. The gold of the ring is, of course, opaque; but the diamond in the setting as you see is invisible since the rays pass through it freely. Here is a radiograph of a shell cameo (Fig. 17) showing its transparency to these rays, in comparison with the gold setting which is opaque.*

The Roentgen rays, like the Crookes rays, have the power of ionizing gases when passed through them; that is, of dissociating them into their ions and thereby rendering them electrolytic conductors. Here is an ordinary gold leaf electroscope kindly loaned me by Professor Hallock. I place it in front of the lantern and throw an image of the gold leaves on the screen. By means of a rod of ebonite, these gold leaves may be charged and, as you

* I am indebted for this slide, as well as for various other excellent radiographs, to my friend Professor A. W. Goodspeed, president of the American Roentgen Ray Society.

see, made to diverge. The Roentgen tube is some feet away from them; and yet you notice that the moment it is put in action, the gold leaves at once fall together; showing that the electroscope has been discharged by the surrounding air, made a conductor by the passage of the Roentgen rays through it. Flame will also ionize air. Exciting the electroscope as before, I hold a lighted match above the divergent gold leaves. The electroscope is discharged and the leaves fall.

It will be observed, therefore, that these rays discovered by Professor Roentgen are entirely different in many of their properties from the Crookes rays. They have also, however, remarkable

FIG. 17. Radiograph.

negative properties which distinguish them from Crookes rays on the one side and from ordinary light rays on the other. From Crookes rays they are distinguished by the fact that they have not been deviated by a magnetic or an electric field; from light rays by the fact that they have not been shown capable of either reflection, refraction or polarization.

Since the Roentgen rays produce luminescence, the inquiry was natural, may not luminescent bodies emit penetrating rays like the Roentgen rays? The experiment was first tried by Professor Henri Becquerel, of Paris, in 1896.* The salts of uranium are known to

* Becquerel, *Comptes Rendus*, cxxii., 420, 501, 689, 762, 1086, 1896; cxxiii., 855; *Rapports au Congrès International de Physique*, Paris, 1900, iii., 47.

luminesce when exposed to sunlight. He placed, therefore, some of the double sulphate of uranium and potassium on a protected plate, the covering absolutely impervious to sunlight, and exposed the whole to the sun. On developing, the plate was found to be darkened. Endeavoring to repeat the experiment, the day was cloudy and the plate as arranged was put away in a drawer. As no sun appeared for two or three days, he finally developed the plate without having exposed it to sunlight, expecting naturally to

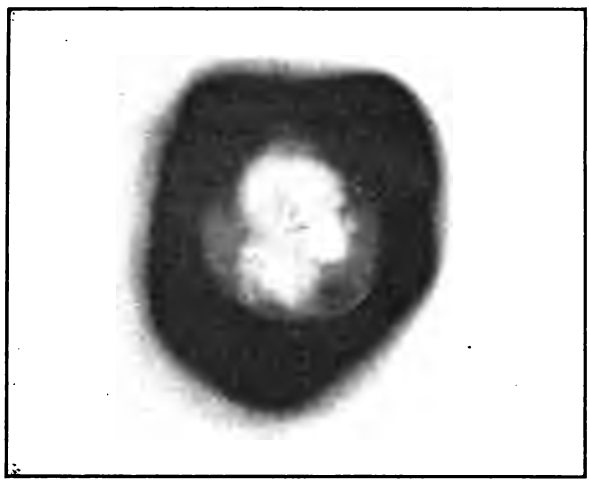


FIG. 18. Uranium radiograph.

get no result. But to his surprise he found that the plate had been very strongly impressed, and, therefore, concluded that the salts of uranium were capable of emitting rays which affected the photographic plate, even when these salts were not luminescent. Although his father many years before had proved that the luminescence of uranium salts was very brief after the removal of the exciting cause, its phosphorescence lasting only the hundredth of a second, he thought that possibly some effect might have been produced upon the uranium salt by the previous exposure of the material to ordinary daylight. So he dissolved the material used, uranium nitrate, in water (substances in the liquid state not being active) and recrystallized it in the dark; and with this new material repeated his experiment. The result was the same as before. Hence this power of emitting penetrating rays,

thus discovered by him, was shown to be a property of the uranium itself and was not dependent upon any previous stimulation. There is now upon the screen the radiograph of a medal (Fig. 18) taken by Becquerel himself with uranium rays. These uranium rays, therefore, thus produced, have since been known as Becquerel rays. I take pleasure in showing you a specimen of metallic uranium obtained from Professor Moissan's laboratory in Paris in 1899. Also several uranium salts such as the nitrate, chloride and especially this beautiful double sulphate of uranium and potassium, the salt with which Professor Becquerel made his first successful ex-

From "Harper's Magazine."
Copyright, 1909, by Harper & Brothers.

FIG. 19.

Professor H. Becquerel.

periments.* Here also is the mineral uraninite, in which polonium, radium and actinium were afterward discovered, and also samarskite, monazite and thorite, minerals all containing uranium and thorium, and, therefore, all radio-active.

In 1898 Madame Sklodowska Curie, of the École Municipale de Physique et de Chimie Industrielle of Paris, undertook to investigate the relative activity of the various salts of uranium in emitting these Becquerel rays, and, subsequently, that of the various minerals containing this metal.† Professor Becquerel, as we have

* I am indebted to Mr. Tucker and Dr. Metzger, of the Havemeyer Laboratory, for preparing for me this double salt as also the corresponding salt of ammonium.

† Sklodowska Curie *Comptes Rendus*, cxxvi., 1101, April, 1898.

seen, had already shown that these rays were capable of darkening the photographic plate. He soon afterward discovered that, like Roentgen rays, they were also capable of discharging electrified bodies, since they ionized and made conductive the air which they traversed. Indeed, he had already made use of this more delicate device for studying the absorption of uranium rays by different substances.* Madame Curie employed the electric method in her investigations and out of the large number of substances examined she obtained two important results: First she proved that the salts of uranium are active in exact proportion to the uranium which they contain; and second, that the uranium minerals are not so proportional. Diagrams of the apparatus used in these measure-

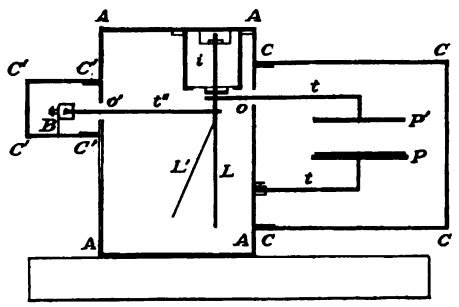


FIG. 20.

ments are shown on the screen. For qualitative examinations she used an electroscope (Fig. 20) having a strip of gold leaf L' which when electrified through the terminal at B is repelled by the metal strip L and diverges. Two plates P and P', on the lower of which the material is placed are connected, the upper plate with the gold leaf and the lower one with the metal case enclosing the apparatus. When the air between the plates becomes ionized the charge passes across and the leaf falls. By noting the time required for this the radio-activity of the substance may be approximately measured. The quantitative apparatus is more elaborate. As you observe (Fig. 21) it consists of two metallic plates, A and B, the lower one connected to one terminal of a battery, P, of 100 volts (the other being put to earth) and the upper one to the electrometer E. When the finely pulverized radio-active substance is placed on the lower plate B it ionizes the air above it and renders it conductive;

* Becquerel, *Comptes Rendus*, cxxii., 559, 1896.

so that, if the upper plate A is earthed through D and C, a current traverses the now closed circuit. On opening the switch at C, the potential of the electrometer is raised and the needle is deflected; the rapidity of the deviation being proportional to the current and therefore serving to measure it. It was found better, however, to measure the counter electromotive force necessary to maintain the needle at zero. As these charges are feeble, this was accomplished by means of a plate of piezoelectric quartz, Q, one armature of which is connected to one of the plates as shown, the other to earth. When by means of weights placed in the scale pan H, a known tension is produced on the plate, it progressively evolves a known potential difference. By regulating the weight so that compensation exists between the quantity of electricity

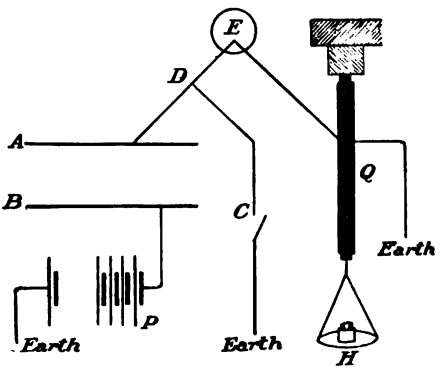


FIG. 21.

traversing the condenser and that of opposite sign yielded by the quartz the absolute value of the quantity of electricity traversing the condenser during a given time; *i. e.*, the current strength, is determined. The current, for example, produced by metallic uranium in this apparatus was found to be 2.3×10^{-11} ampere; that of sodium uranate 1.2×10^{-11} ampere and that of potassium-uranyl sulphate 0.7×10^{-11} ampere; while the mineral monazite gave a current of 0.5, chalcolite a current of 5.2, and uraninite of 8.3 $- 10^{-11}$ ampere.

From all this it follows first, that in its salts the uranium must be the active material; and second, on the other hand that it cannot be the chief active material in its minerals. For example, as just stated, the mineral uraninite (or pitch-blende, as it is frequently termed), was found to be four times as active as metallic uranium

itself. Hence it is quite impossible to believe that the radio-activity of the uraninite is due to the uranium which it contains. Convinced that in this mineral, therefore, there was some other and far more active element, Mme. Curie set herself at work to obtain this element by the usual chemical methods; and in July, 1898, she communicated to the Academy of Sciences of Paris a paper, which was presented by

Professor P. Curie, Madame S. Curie and Mlle. Irene Curie.*

Professor Becquerel, announcing the discovery of a new radio-active substance in uraninite which resembled bismuth.† Supposing this to be a new element she gave it the name of polonium, from Poland her native country. In the following December the Academy awarded her the Gegner prize of 4,000 francs for her discovery.

* We are indebted for this cut to the courtesy of the New York *Tribune*.

† Mme. Curie, *Comptes Rendus*, cxxvii., 175. *Rapports au Congrès International de Physique*, iii., 79, Paris, 1900.

Continuing her investigations, in which she was assisted by her husband, M. Pierre Curie, who is the professor of chemistry, and with M. Bemont, who is the Director of the École Municipale, she finally succeeded in obtaining a second radio-active substance from uraninite, one hundred thousand times as active as uranium; naturally it was agreed to call this new substance radium. The quantity of this material in the mineral is absolutely infinitesimal. To obtain it thousands of kilograms of the uranium residues from Bohemia were worked up and yielded only a few decigrams of substance. But this, though still impure, was prodigiously active. It is estimated that 5,000 tons would be necessary to obtain a single pound of radium, and this far from pure. Pitchblende is estimated to contain less than $\frac{1}{10000000}$ of one per cent. of this substance; less than there is gold in the waters of the ocean. The discovery of radium, therefore, could not have been made except for the extraordinary delicacy of the electric method. It has been shown by Rutherford that the quadrant electrometer will detect 3×10^{-18} gram of hydrogen.* The most delicate balance will indicate only one millionth of a gram. Whence it follows that the electric method is a million million times more delicate than the balance method. By the accumulation of charge, therefore, the electrometer will detect in one minute an amount of matter requiring 2,000,000 years for its detection by the balance. "Matter may be recognized in a few minutes by the electrometer which would require geological epochs to increase so as to be detected by the balance" (Rutherford). But more than this. The electric method as a means of investigation is vastly more delicate than even the method of spectrum analysis. The spectroscope, we are told, will detect by the spark method one hundred millionth of a milligram of strontium; while the electric method will detect a quantity of radium as small as one five-thousandth part of this minute quantity.

The total amount of radium which has thus far been produced is exceedingly small, probably not a pound in all, and even this exists only in various degrees of purity. The purest which has thus far been obtained, Madame Curie tells us, is one hundred thousand times as active as uranium. A friend informs me that he saw a minute quantity of this pure material in Professor Curie's labora-

* E. Rutherford, *Phil. Mag.*, VI., iv., 370, Sept., 1902.

tory in Paris, a few months ago, having about the volume of an ordinary buck shot and weighing three centigrams, and which Professor Curie said he would not part with for 100,000 francs.

The spectrum of the purest radium in the possession of the Curies was obtained by Demarçay, and as he observed in it certain lines not known to belong to any other element, it was concluded that radium was a new element. Madame Curie has determined its atomic mass at intervals as the purification went on, the first value obtained being 135. As radium in its chemical relations is very closely allied to barium, and as its separation from barium is the process required to increase its purity, the test of this purity, as barium is not ordinarily radio-active, is the relative brightness of the radium lines in the spectrum as compared with the barium lines. As the above atomic mass, 135, is very close to that of barium, 136, it has been difficult to discriminate between them ; but as the purification proceeded the atomic mass was raised, first to 174, and subsequently to 225.

In the same year, 1898,* G. C. Schmidt and, a month later, Madame Curie discovered that salts of the element thorium also possessed radio-active properties ; and in 1899 Debierne discovered a third radio-active substance in uraninite allied to iron, which he called actinium.† The rays emitted by all these radio-active substances, or, in other words, the Becquerel rays, are all similar. They have penetrating powers ; they effect the photographic plate ; they are more or less deviable by the magnet; they produce luminescence and they ionize gases and render them conducting. In fact radium is self-luminous in the dark, apparently from the action of its own Becquerel rays upon itself, acting as a luminescent body. It is to be noted that the atomic mass of uranium is 240, that of thorium is 232 and that of radium 225 ; that of polonium and of actinium not having been determined. Since these are the highest atomic masses known among the elements, there would seem to be indicated some relation between the radio-activity of an element and its atomic mass.

Thanks to the courtesy of several friends, I am able to-night to show you samples of these new radio-active substances. The first radium which I ever saw was shown to me in London by Professor

* Schmidt, *Verh. Phys. Ges. Berlin*, xvii., 14, Feb., 1898; *Ann. Phys. Chem.*, lxv., 141, March, 1898. Curie, *Comptes Rendus*, cxxvi., 1101, April, 1898.

† Debierne, *Comptes Rendus*, cxxix., 593, 1899; cxxx., 906, 1900.

Becquerel in 1899 at the Centennial celebration of the Royal Institution of Great Britain. These two samples, marked respectively *A* and *B*, were subsequently purchased from de Haen, of Hanover, a few months later and brought home. The *A* sample was capable of producing luminescence of the barium platino-cyanide screen, even through a thin aluminum plate; it acted on the photographic film and rendered the air about it a conductor. In addition, it had a very intense self-luminescence, being distinctly visible in the dark. The *B* sample — though its rays acted on the barium platino-cyanide screen more intensely and had more penetrating power, its self-luminescence was greatly less. Although both these samples were preserved in glass-stoppered bottles, moisture has gained access to them and their radio-activity has diminished considerably. Here is a sample of the subnitrate of polonium and three specimens of chloride of barium and radium, made by the Société Centrale de Produits Chimiques, and imported from Paris by the Smithsonian Institution. I am indebted to Professor Langley for the use of them. The radium specimens have an activity 240 times that of uranium. And as they are hermetically sealed, they are clearly visible in the dark, as you see, although they have been in this country three years or more. By the kindness of Mr. W. J. Hammer, I can show you three other samples of the radio-barium chloride, obtained by him in Paris six months or more ago, whose radio-activity is respectively 300, 1,000 and 3,000 times that of uranium; the last two being brightly luminous. The price of this last material was 300 francs a gram.* I have also upon the table samples of thorium oxide, ammonium-thorium nitrate, and thorium oxalate made from the mineral monazite on the large scale, as thoria is the efficient material in the Welsbach mantle. For them I am indebted to Dr. Chandler's superb museum.

In proof of the photographic action of these radio-active bodies, I here exhibit several radiographic plates made with them in December, 1899. The first one, protected by enclosing it in a black inner and an orange outer envelope of paper, had placed upon it specimens of metallic uranium, of uranium chloride and nitrate, of uraninite and of radium *A* and *B*. On developing after eight hours, all the substances had impressed the film, as you see, in the following order: Radium *A* and *B*, uraninite, uranium, uranium chloride, uranium nitrate. The second plate, similarly protected, was ex-

* The Société Centrale furnishes also a product 7000 times as active as uranium at 500 francs a gram.

posed in the same way for 24 hours except that beneath each material was placed a thin sheet of metal in order to show the different penetrating power of the rays. The third plate used uraninite as the active material, the metallic films, all about .0025″ in thickness, being platinum, lead, silver, copper, tin and aluminum. On exposing for 16 hours, the films were found to be opaque in the order given. To test the activity of the radium, three successive exposures were made on different parts of the same plate, one of 15 minutes, one of an hour and one of three hours. The darkening of the film is seen to be proportional to the time of exposure. Similar experiments were made with thorium. In this plate is

FIG. 23. Radium photograph.

seen the effect of monazite and thorite as compared with thorium oxide and nitrate. The activity is proportional to the content of the substance in thorium.

That radium emits both visible and invisible rays can be easily shown by their photographic effect. Here is a *photograph* of a sailboat taken by Dr. H. C. Bolton of Washington by the visible or light rays from radium, the plate being exposed under a negative in the ordinary way, for two hours at 2¾ inches distance. This other picture is a *radiograph* of a mouse taken in the dark by Mr.

W. J. Hammer, of this city, by exposing the plate with the mouse upon it, to the invisible Becquerel rays for twenty-four hours.

It would be interesting to show you the ionizing effect of these radio-active bodies. But as you see, the electroscope will not take a charge, the air all about it having been rendered conducting, first by the Roentgen rays shown a while ago, and now by the Becquerel rays from the radio-active substances upon the table. Becquerel showed some time ago that metallic uranium could be made to hold an electric charge only in a vacuum.

Since the discovery of these remarkable rays, emitted spontaneously and apparently without any supply of external energy, the question becomes of very great importance, what is the nature of these Becquerel rays, as compared with the rays of Roentgen and of Crookes? This question has occupied the attention of some

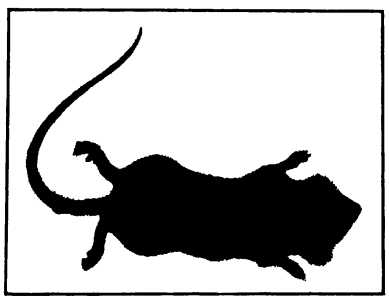


FIG. 24. Radium radiograph.

of the ablest physicists of all countries. In 1899, Giesel showed that the rays of the radio-active substances contain a portion deviable by the magnet. And soon afterwards Becquerel and the Curies proved the Becquerel rays to be heterogeneous, one part being deviable and the other non-deviable. In the picture now on the screen, (Fig. 25) representing radium rays passing through a slit into a magnetic field you notice that while one portion continues straight on, the other portion is deviated to the right and diffused. The latest conclusion on the subject has been given us by Professor Rutherford, of Montreal, during the present year. He classifies the Becquerel rays emitted by radium,* already proved to be composite, as of three kinds; first, alpha rays, which are very

* E. Rutherford, *Phil. Mag.*, VI., v., 177, February, 1903.

feebly penetrating and which therefore are easily absorbed by thin layers of matter; they constitute by far the greater portion of all radio-active rays; second, beta rays, which are negatively charged particles moving with a high velocity and which are in all respects like ordinary Crookes rays; and, third, gamma rays, which are not deviated by a magnetic field, and yet, which are of a highly penetrating character. While, for example, the alpha rays will not penetrate an aluminum plate more than $\frac{5}{10000}$ of a centimeter thick, the beta rays will penetrate such a plate $\frac{5}{100}$ of a centimeter and the gamma rays a plate 8 centimeters thick; these thicknesses being required in each case to reduce the rays to one half their original intensity. The rays from polonium ap-

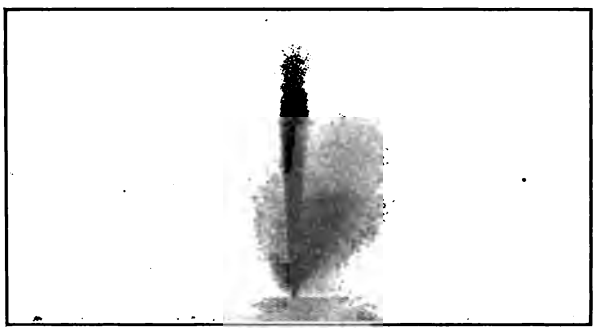


FIG. 25. Becquerel rays composite.

pear to consist entirely of alpha rays; those from uranium to consist entirely of beta rays, and those from radium and thorium to consist of all three.

Since the rays emitted by radio-active substances consist in part at least of material corpuscles having a high velocity, it is evident that there must be a loss of matter going on continuously. Madame Curie estimates that radium emits from each square centimeter of surface 1.2 milligrams of matter in 1,000,000,000 years; so that at this rate it would be impossible to observe directly any loss in mass by the most delicate balances at present available during 2,000,000 years; *i. e.*, during a geologic epoch, as Professor Rutherford puts it.

The energy of these corpuscles is so enormous that although exceedingly minute the energy effect is considerable. It is estimated that the energy emitted from each square centimeter of

radium would melt a layer of ice of the same area and a quarter of a mile thick in a million years; and as Lord Kelvin has pointed out, this emission of matter and the corresponding loss of energy has apparently been going on indefinitely in the past and will continue to go on indefinitely in the future. It is extremely difficult to understand how such emission of energy without any conceivable source of supply does not conflict with the great and fundamental law of the conservation of energy. It is still more remarkable that in the case of these radio-active substances the speed with which the corpuscles move is very much greater than it is even in the case of the Crookes rays. Becquerel has shown that the speed of radium rays is as high as 120,000 miles a second, which is two thirds of the speed of light; and certain other inves-

FIG. 26. Professor E. Rutherford.

tigators especially Kaufmann have obtained even a higher velocity, 2.8×10^{10} centimeters per second having been measured.

A most important fact, however, which has been recently discovered by Rutherford, is the fact of the deviability of the alpha rays of radio-active substances. He has shown that the deviation of these rays has not been observed because of the fact that the magnetic field was not sufficiently powerful. Using a field of 8,400 C.G.S. units and a radium specially furnished by Professor Curie which had an activity 19,000 times that of uranium, he has succeeded in deviating the alpha rays completely. Moreover, from this deviation he has also succeeded in determining the speed of the par-

ticles and in ascertaining their mass. He finds their speed to be 2.5×10^9 centimeters per second, and the ratio of their mass to their charge m/e to be 1.6×10^{-4}. Hence it will be observed that the velocity is lower and the mass greater than that of the Crookes corpuscles. Moreover, the deviation which he has observed is in the opposite direction to that of the Crookes' rays. If the deviation in the one direction indicates that the particles are charged negatively, the deviation in the other direction, correspondingly indicates that the particles are charged positively. It would seem, therefore, that while the Crookes rays consist of particles of the order of a thousandth of the mass of a hydrogen atom charged negatively, the α Becquerel rays consist of particles of a mass of the order of the hydrogen atoms themselves, charged positively. In other words, the negative corpuscles being driven out from the atom the rest of the atom is left positively electrified, and being of much larger mass, is driven out under the same conditions with a less velocity. Hence therefore these rays require a much stronger magnetic field to affect their deviation. The carriers of negative electrification, consequently, are excessively minute and their mass is invariable; the carriers of positive electrification are comparatively large and their mass is variable.

The chemical action of Becquerel rays was early observed by Becquerel and the Curies.* They noticed that these rays ozonized oxygen, that silver salts and the higher oxide of iron were reduced when exposed to them; that the color of glass and of porcelain was changed to purplish, owing to oxidation, and rock salt was turned blue under their influence. Their photographic effect also supports this hypothesis.

One of the most remarkable effects observed with Becquerel rays has been the physiological one. Geisel observed that the radiation produced inflammation. Becquerel carried a sealed tube which contained a few decigrams of very active material in his pocket for six hours. Ten days afterwards a red spot appeared opposite the pocket and twenty days later it suppurated. After forty-nine days the ulcer closed leaving a distinct scar. The same tube enclosed in lead gave no effect in forty hours. Professor Curie used a radium 5,000 times as active as uranium, wrapping it in thin rubber and placing it on his arm. After a few hours the

* *Comptes Rendus*, cxxxiii., 709, 1901; cxxxii., 1289; cxxix., 823, 1899.

skin was reddened, resembling a burn; on the twentieth day a sore was developed which required a surgical dressing and only on the forty-second day did it begin to heal. It was still sore on the fifty-second day after the experiment. In consequence of these results, Professor Curie said he would not like to trust himself in a room with one kilogram of pure radium, as it would no doubt destroy his sight, burn all the skin off his body and probably kill him. He showed the scars upon his arms, the result of the above ulcer which had taken fifty-two days to heal, and another scar where the skin had been blistered, caused by five minutes' exposure to radium of high activity.

Within the present month, MM. Curie and Laborde have announced* that radium compounds have the remarkable property of emitting heat spontaneously. Their investigations show that a gram of ordinary radiferous barium chloride evolves about 14 calories per hour. Experiments on a purer material lead them to the conclusion that one gram of pure radium would evolve 100 calories per hour. In other words a gram-atom (225 grams) of radium would evolve in an hour 22,500 calories; a quantity comparable with that produced by one gram-atom of hydrogen burning in oxygen. Such a continuous evolution of heat cannot be explained by an ordinary chemical transformation. If its origin lies in internal changes it must arise from a modification of the atom itself.

The noteworthy fact has been developed by various investigators that this radio-activity is a property capable of being communicated from radio-active substances to other bodies.† Madame Curie finds that any substance placed in the neighborhood of radium acquires radio-activity which it retains for many hours. The metals zinc, iron and lead, the fittings and the air of the laboratory, the clothing of the workers in it and the bodies of the workers themselves, all become radio-active. For days Professor Curie was unable to enter his laboratory or to approach his electrometer, owing to the fact that exposure to radio-active substances had made his clothing and his person so radio-active as to affect the instruments.

A still more remarkable fact is that discovered by Rutherford in 1900, that thorium gives off what he calls an emanation, this eman-

---

* *Comptes Rendus*, cxxxvi., 673. J. J. Thomson, *Nature*, lxvii., 601, 1903.

† Curie & Debierne, *Comptes Rendus*, cxxxiii., 133, 1901.

ation being of the nature of a gas and very highly radio-active.* It diffuses through gases and liquids and even porous substances. Passed over ignited platinum black, lead chromate, etc., it comes out unchanged. It cannot enter into combination with any known substances. It is a chemically inert gas like argon, helium, neon, krypton and xenon, and hence appears to be a new member of the argon family with an atomic mass between forty and one hundred. The emanation from thorium liquefies at — 120° and that from radium at — 150°.

This emanation he considers to be the result of successive chemical changes in the thorium. The thorium atom produces a substance, thorium *X*, by a chemical change therein; by a further and also apparently a chemical change, this thorium *X* produces the emanation. This emanation then expels from itself a negatively charged body constituting the Becquerel rays, and finally the residue positively charged goes to the electrodes and undergoes further chemical changes, giving rise to an excited radio-activity.

Moreover he has shown that only those radio-active substances which emit emanations can excite radio-activity. Radium and thorium therefore possess this power while uranium and potassium do not.

Another important fact is the fact that Elster & Geitel have shown, that substances may be made radio-active by hanging them up in the air and charging them strongly with negative electricity. They have taken radiographs with the scrapings of a copper rod thus treated. The earth, as we know, is negatively electrified and this on pointed conductors makes them radio-active. The terminals of lightning rods and the leaves and spines upon trees are radio-active, as Thomson has pointed out. Wilson has shown that freshly fallen rain and snow are radio-active. Hence, it would seem that radio-activity is a universal phenomenon possessed by all bodies upon the earth's surface in greater or less degree.

In closing this address, I am sure you will permit me to express my thanks for your kind and courteous attention; and further that you will join me in expressing to Dr. L. H. Laudy the great obligations we are under for his efficient aid in presenting so successfully the experimental illustrations.

---

* Rutherford, *Phil. Mag.*, V., xlix., 1, 1900. *Ib.*, VI., v., 561, 1903. *Chem. News.*, lxxxv., 55, 1902.

PARTIAL BIBLIOGRAPHY.

A. Crookes or Kathode Rays.

1. On the Illumination of Lines of Molecular Pressure and the Trajectory of Molecules. W. Crookes. *Phil. Trans.*, 1879, clxx., 135.
2. Contributions to Molecular Physics in High Vacua. W. Crookes. *Phil. Trans.*, 1879, clxx., 641.
3. On Radiant Matter. W. Crookes. *Nature*, xx., 419, 436, 1879. (Lecture delivered before the British Association at Sheffield.)
4. Electricity in Transitu: from Plenum to Vacuum. W. Crookes. *Proc. Inst. Elec. Engineers*, xx., 4–49, 1891. (Lecture delivered before the Institute January 15th.)
5. Experiments on the Discharge of Electricity through Gases. Sketch of a Theory. A. Schuster. *Proc. Roy. Soc.*, xxxvii., 317, 1884; Second paper, xlii., 371, 1887.
6. Die Magnetische Ablenkung der Kathodenstrahlen. A. Schuster. *Ann. Phys. Chem.*, II., lxv., 877, 1898.
7. The Disruptive Discharge of Electricity through Gases. A. Schuster. *Phil. Mag.*, V., xxix., 182, 1890. (Roy. Soc. Bakerian Lecture.)
8. Nouvelles propriétés des rayons cathodiques. J. Perrin. *Comptes Rendus*, cxxi., 1130, 1895. *Ann. Chim. Phys.*, VII., xi., 496.
9. On Cathode Rays. J. J. Thomson. *Phil. Mag.*, V., xliv., 293, 1897.
10. On the Theory of the Conduction of Electricity through Gases by charged Ions. J. J. Thomson. *Phil. Mag.*, V., xlvii., 253, 1899.
11. On the Masses of the Ions in Gases at low Pressures. J. J. Thomson. *Phil. Mag.*, V., xlviii., 547, 1899.
12. The Existence of Bodies smaller than Atoms. J. J. Thomson. *Proc. Roy. Inst.*, xvi., 574, 1901.
13. Cathode Rays. J. J. Thomson. *Harper's Magazine*, ciii., 564, Sept., 1901.
14. Experiments upon the Cathode Rays and their Effects. A. W. Wright. *Am. J. Sci.*, IV., i., 235, 1896.
15. Triangulation by means of the Cathode Photography. J. Trowbridge. *Am. J. Sci.*, IV., i., 245, 1896.
16. Note on the Magnetic Deflection of Cathode Rays. H. A. Wilson. *Proc. Phil. Soc. Cambridge*, xi., 179-182, 1901.
17. Ueber Luminescenz von festen Körpern und festen Lösungen. E. Wiedemann and G. C. Schmidt. *Ann. Phys. Chem.*, II., lvi., 201–254, 1897.
18. Untersuchungen über die electrische Entladung in verdünnten Gasen. W. Wien, *Ann. Phys. Chem.*, II., lxv., 440–452, 1898.
19. Sur les rayons cathodiques. Villard. *Comptes Rendus*, cxxvi., 1564; cxxvii., 173, 223, 1898.
20. Sur les rayons cathodiques *simples*. E. Goldstein. *Comptes Rendus*, cxxvii., 318, 1898.
21. Remarques sur les rayons cathodiques simples. H. Deslandres. *Comptes Rendus*, cxxvii., 1210, 1898.
22. The Dispersion of the Cathode Rays by Magnetic Force. R. J. Strutt. *Phil. Mag.*, V., xlviii., 478, 1899.
23. Die magnetische Ablenkbarkeit electrisch besinflusster Kathodenstrahlen. W. Kaufmann. *Verh. Phys. Ges. Berlin*, xvii., 58, 1898.

24. Ueber die Reflexion der Kathodenstrahlen. H. Starke. *Verh. Phys. Ges. Berlin*, xvii., 76, 1898.
25. Ueber sichtbare und unsichtbare Kathodenstrahlen. E. Goldstein. *Verh. Phys. Ges. Berlin*, II., iii., 192, 203, 1901.
26. Sur l'emploi de la blende hexagonale artificielle pour remplacer les ampoules de Crookes. L. Troost. *Comptes Rendus*, cxxii., 564, 1896.
27. Ueber die diffuse Zerstreuung der Kathodenstrahlen in verschiedenen Gasen. W. Kaufmann. *Ann. Phys. Chem.*, lxix., 95, 1899.
28. Sur les rayons cathodiques. P. Villard. *J. Phys.*, III., viii., 1–16, 148, 1899.
29. Ueber die Chemische Wirkung der Kathodenstrahlen. G. C. Schmidt. *Phys. Zeitschr.*, iii., 114–115, 1902.
30. Production des rayons cathodiques par les rayons ultraviolets. Lamotte. *J. Phys.*, IV., i., 778–784, 1902.
31. On the charge of Electricity carried by Gaseous Ions. J. J. Thomson. *Phil. Mag.*, VI., v., 346, 1903.
32. Cathode Rays and the Constitution of Matter. J. J. Thomson. *Rapports presentés au Congrès International de Physique*, Paris, 1900, III., 138.
33. Beiträge zur Kenntniss der Kathodenstrahlen. W. Seitz. *Ann. Phys.*, IV., vi., 1–33, 1901.

B. Lenard and Roentgen Rays.

1. Ueber Kathodenstrahlen in Gasen von atmosphärischene Drucke und in äussersten Vacuum. Ph. Lenard. *Ann. Phys. Chem.*, II., li., 225–267, 1894.
2. Ueber die Absorption der Kathodenstrahlen. Ph. Lenard. *Ann. Phys. Chem.*, II., lvi., 255–275, 1895.
3. Ueber die electrische Wirkung der Kathodenstrahlen auf atmosphärische Luft. Ph. Lenard. *Ann. Phys. Chem.*, II., lxiii., 253–260, 1897.
4. Ueber eine neue Art von Strahlen. W. C. Roentgen. *Sitzungsberichte der Würzburger Phys.-Med. Ges.*, 1895. *Nature*, liii., 274, 1896; *Ann. Phys. Chem.*, II., lxiv., 1, 12, 1898.
5. Weitere Beobachtungen über die Eigenschaften der X Strahlen. W. C. Roentgen. *Ber. Ak. Berlin.*, 1897. *Ann. Phys. Chem.*, II., lxiv., 18, 1898.
6. Notes of Observations on the Roentgen Rays. H. A. Rowland, N. R. Carmichael and L. J. Briggs. *Am. J. Sci.*, IV., i., 247, 1896.
7. On the Laws of Conduction of Electricity through Gases exposed to the Röntgen Rays. J. J. Thomson and E. Rutherford. *Phil. Mag.*, V., xlii., 392, 1896.
8. Presidential Address, Liverpool meeting British Association. J. J. Thomson. *Rep. British Association*, 1896, 699.
9. Action des rayons X sur les corps électrisés. Benoist and Hurmuzescu. *Comptes Rendus*, cxxii., 779, 926, 1896.
10. Quelques propriétés des rayons de Röntgen. J. Perrin. *Comptes Rendus*, cxxii., 186, 1896.
11. Nouvelles propriétés des rayons X. L. Benoist and D. Hurmuzescu. *Comptes Rendus*, cxxii., 235, 379, 1896.
12. Transparence des metaux pour les rayons X. V. Chaband. *Comptes Rendus*, cxxii., 237, 1896.
13. Influence de la nature chimique des corps sur leur transparence au rayons de Röntgen. M. Meslans. *Comptes Rendus*, cxxii., 309, 1896.
14. Sur l'action physiologique des rayons X. W. Crookes. *Comptes Rendus*, cxxiv., 855, 1897.

15. Origine des rayons de Röntgen. J. Perrin. *Comptes Rendus*, cxxii., 716, 1896. *Ann. Chim. Phys.*, VII., xi., 575.
16. Décharge par les rayons de Röntgen. Rôle des surfaces frappées. J. Perrin. *Comptes Rendus*, cxxiv., 496, 1897.
17. On the Velocity and Rate of Recombination of the Ions of Gases exposed to Röntgen Radiation. E. Rutherford. *Phil. Mag.*, V., xliv., 422, 1897.
18. Application des rayons de Röntgen à la mesure des forces electromotrices de contact. J. Perrin. *Comptes Rendus*, cxxiv., 496, 1897; *Ann. Chim. Phys.*, VII., xi., 503.
19. On the Conductive effect produced in air by Röntgen Rays and by ultraviolet light. Kelvin, Beattie & De Smolan. *Nature*, lv., 344, 447, 1896.
20. On the Fall of Potential at the surface of a metal when exposed to the Discharging Action of the X-Rays. C. D. Child. *Phys. Rev.*, vi., 285, 1898.
21. A Theory of the Connection between Cathode and Röntgen Rays. J. J. Thomson. *Phil. Mag.*, V., xlv., 172–183, 1898.
22. The Source of the X-Rays. J. Trowbridge and J. E. Burbank. *Phil. Mag.*, V., xlv., 185–191, 1898.
23. On the Discharge of Electricity produced by the Röntgen Rays and the Effects produced by these Rays on Dielectrics through which they pass. J. J. Thomson. *Proc. Roy. Soc.*, lix., 274, 1896.
24. Ueber ein noch nicht untersuchte Strahlungsform an der Kathode inducirte Entladungen. E. Goldstein. *Ann. Phys. Chem.*, II., lxiv., 38, 1898.
25. Sur l'action chimique des rayons X. Villard. *Comptes Rendus*, cxxix., 882, 1899.
26. Cathode, Lenard and Röntgen Rays. Wm. Sutherland. *Phil. Mag.*, V., xlvii., 269–284, 1899.
27. Note on Mr. Sutherland's paper on the Cathode Rays. J. J. Thomson. *Phil. Mag.*, V., xlvii., 415, 1899.
28. Methode de determination des poids atomiques fondée sur les lois de transparence de la matière pour les rays X. L. Benoist. *Comptes Rendus*, cxxxii., 772, 1901.
29. On the Discharge of Electricity produced by the Röntgen Rays and the Effects produced by those rays on Dielectrics through which they pass. J. J. Thomson. *Proc. Roy. Soc.*, lix., 274, Feb., 1896.
30. Ueber Kanalstrahlen. E. Goldstein. *Verh. Phys. Ges. Berlin*, II., iii., 204–212, 1901.
31. Ein neuer Versuch mit Lenard'schen Strahlen. Th. Des Coudres. *Verh. Phys. Ges. Berlin*, xvii., 17, 60, 1898.
32. Die electrostatische und magnetische Ablenkung der Kanalstrahlen. W. Wien. *Verh. Phys. Ges. Berlin*, xvii., 10, 1898.
33. Conductance produced in Gases by Röntgen Rays, by Ultra-violet Light and by Uranium and some Consequences thereof. Beattie and De Smolan. *Phil. Mag.*, V., xliii., 418; xlv., 277, 1897.
34. Sur le méchanisme de la decharge des conducteurs frappées par les rayons X. G. Sagnac. *Comptes Rendus*, cxxvi., 36, Jan., 1898.
35. Caractères de la transformation des rayons X par la matière. G. Sagnac. *Comptes Rendus*, cxxvi., 887, March, 1898.
36. Transformations des rayons X par la matière. G. Sagnac. *J. Phys.*, III., viii., 65, Feb., 1899.
37. Décharge par les rayons de Röntgen. Effet secondaire. J. Perrin. *Comptes Rendus*, cxxvi., 243, 1898.

C. BECQUEREL RAYS.

1. Augmentation du rendement photographique du rayons Roentgen par le sulfure de zinc phosphorescent. Ch. Henry. *Comptes Rendus*, cxxii., 312, 1896.
2. Sur la propriété qu'ont les radiations émises par les corps phosphorescents de traverser certains corps opaques à la lumière solaire, et sur les experiences de M. G. Le Bon sur la lumière noire. Niewenglowski. *Comptes Rendus*, cxxii., 385–6, 1896.
3. Sur les radiations émises par phosphorescence. H. Becquerel. *Comptes Rendus*, cxxii., 420, Feb., 1896.
4. Sur les radiations invisible émises par les corps phosphorescents. H. Becquerel. *Comptes Rendus*, cxxii., 501, 1896.
5. Sur quelques propriétés nouvelles des radiations invisibles émises par divers corps phosphoresents. H. Becquerel. *Comptes Rendus*, cxxii., 559, 1896.
6. Sur les radiations invisibles émises par les sels d'uranium. H. Becquerel. *Comptes Rendus*, cxxii., 689, 1896.
7. Sur les propriétés differents des radiations invisibles émises par les sels d'uranium, et du rayonnement de la paroi anticathodique d'une tube de Crookes. H. Becquerel. *Comptes Rendus*, cxxii., 762, 1896.
8. Emission des radiations nouvelles par uranium metallique. H. Becquerel. *Comptes Rendus*, cxxii., 1086, 1896.
9. Sur diverses propriétés des rayons uraniques. H. Becquerel. *Comptes Rendus*, cxxxiii., 855, 1896.
10. Recherches sur les rayons uraniques. H. Becquerel. *Comptes Rendus*, cxxiv., 438, 1897.
11. Sur la loi de la décharge dans l'air de l'uranium éléctrisé. H. Becquerel. *Comptes Rendus*, cxxiv., 800, 1897.
12. Rayons émis par les composés de l'Uranium et du Thorium. Mme. Sklodowska Curie. *Comptes Rendus*, cxxvi., 1101, April, 1898.
13. Sur une substance nouvelle radioactive contenue dans la pechblende. P. & S. Curie. *Comptes Rendus*, cxxvii., 175, July, 1898.
14. Sur une nouvelle substance fortement radioactive contenue dans la pechblende. P. & S. Curie, and Bemont. *Comptes Rendus* , cxxvii., 1215, Dec., 1898.
15. Ueber die von den Thorverbindungen und einigen anderen Substanzen ausgehende Strahlung. G. C. Schmidt. *Verh. Phys. Ges. Berlin*, xvii., 14, Feb., 1898; *Ann. Phys. Chem.*, II., lxv., 141, 1898.
16. Note sur quelques propriétés du rayonnement de l'uranium et des corps radioactifs. H. Becquerel. *Comptes Rendus*, cxxviii., 771, 1899.
17. Recherches sur les phénomenes de phosphorescence produits par le rayonnement du radium. H. Becquerel. *Comptes Rendus*, cxxix., 912, 1899.
18. Sur le spectre d'un substance radioactive. Demarçay. *Comptes Rendus*, cxxvii., 1218, 1899.
19. Sur la source de l'energie dans les corps radioactifs. W. Crookes. *Comptes Rendus*, cxxviii., 176, 1899.
20. Sur une nouvelle matière radio-active. Debierne. *Comptes Rendus*, cxxix., 593, 1899.
21. Effets chimiques produits par les rayons de Becquerel. P. and S. Curie. *Comptes Rendus*, cxxix., 823, 1899.
22. Sur le spectre du radium. Demarçay. *Comptes Rendus*, cxxix., 716, 1899.
23. Sur le poids atomique du metal dans le chlorure de baryum radifère. Mme. S. Curie. *Comptes Rendus*, cxxix., 760, 1899.

22. Sur la radio-activité provoquée par les rayons de Becquerel. P. and S. Curie. *Comptes Rendus*, cxxix., 714, 1899.
23. Sur le rayonnement des corps radio-actifs. H. Becquerel. *Comptes Rendus*, cxxix., 1205, 1899.
24. Influence d'un champ magnetique sur le rayonnement des corps radio-actifs. H. Becquerel. *Comptes Rendus*, cxxix., 996, 1899.
25. Becquerel Rays. Elster and Geitel. *Ann. Phys. Chem.*, II., lxvi., 735; lxix., 83.
26. Ueber eine radioactive Substanz. de Haen. *Ann. Chem. Phys.*, II., lxviii, 902, 1899.
27. Uranium Radiation and the Electrical Conduction produced by it. E. Rutherford. *Phil. Mag.*, V., xlvii., 109–163, 1899.
28. Thorium Radiation. R. B. Owens. *Phil. Mag.*, V., xlviii., 359, 1899.
29. Action du champ magnetique sur les rayons de Becquerel. Rayons devies et rayons non-deviés. P. Curie. *Comptes Rendus*, cxxx., 73, 1900.
30. Sur la penetration des rayons de Becquerel non-deviable par le champ magnetique. Mme. S. Curie. *Comptes Rendus*, cxxx., 76, 1900.
31. Sur la charge electrique des rayons deviable des radiums. P. and S. Curie. *Comptes Rendus*, cxxx., 647, 1900.
32. Electrization negative des rayons secondaires produits au moyens des rayons Röntgen. P. Curie and Sagnac. *Comptes Rendus*, cxxx., 1013, 1900.
33. Sur le poids atomique du baryum radifère. Mme. S. Curie. *Comptes Rendus*, cxxxi., 382, 1900.
34. Sur un nouvel élément radio-actif; l'actinium. Debierne. *Comptes Rendus*, cxxx. 906, 1900.
35. Sur du baryum radioactive artificiel. Debierne. *Comptes Rendus*, cxxxi., 333, 1900.
36. Fluorescence de certains composés metalliques soumis aux rayons Röntgen et Becquerel. Paul Bary. *Comptes Rendus*, cxxx., 776, 1900.
37. Sur le spectre du Radium. Demarçay. *Comptes Rendus*, cxxxi., 258, 1900.
38. Contribution à l'etude du rayonnement du radiums. H. Becquerel. *Comptes Rendus*, cxxx., 206, 1900.
39. Sur la dispersion du rayonnement du radium dans un champ magnetique. H. Becquerel. *Comptes Rendus*, cxxx., 372, 1900.
40. Deviation du rayonnement du radium dans un champ electrique. H. Becquerel. *Comptes Rendus*, cxxx., 809, 1900.
41. Sur le rayonnement de l'uranium et sur diverses propriétés physiques du rayonnement des Corps Radioactifs. H. Becquerel. *Rapports presentés au Congrès International de Physique*, Paris, 1900, III., 47.
42. Les nouvelles Substances Radioactives et les Rayons qu'elles émittent. P. Curie and Mme. S. Curie. *Rapports presentés au Congrès International de Physique*, Paris, 1900, III., 79.
43. Ueber die vom Thorium und den Thorverbindungen ausgehande Strahlen. G. C. Schmidt. *Verh. Phys. Ges., Berlin*, xvii., 14, 1898.
44. Ein einfaches und empfindliches Quadranten-electrometer. Dolezalek. *Verh. Phys. Ges., Berlin*, II., iii., 18, 1901.
45. Ueber die Ablenkbarkeit der Becquerelstrahlen im magnetischen Felde. F. Giesel. *Ann. Phys. Chem.*, II., lxix., 834, 1899.
46. Note sur le rayonnement de l'uranium. H. Becquerel. *Comptes Rendus*, cxxx., 1583, 1900.
47. Sur le rayonnement de l'uranium. H. Becquerel. *Comptes Rendus*, cxxxi., 137. *Chem. News*, lxxxii., 83, 1900.

48. The Energy of Röntgen and Becquerel Rays and the Energy required to produce an ion in gases. Rutherford and McClung. *Proc. Roy. Soc.*, lxvii., 245, 1900.
49. The Radioactivity of Thorium compounds. Rutherford and Soddy. *Chem. News*, lxxxv., 271, 293; lxxxvi., 97, 1900.
50. Emanations from Radioactive Substances. Rutherford. *Nature*, lxiv., 157, 1900.
51. An Experimental Study of Radioactive Substances. H. C. Bolton. *Jour. Am. Chem. Soc.*, xxii., 596, 1900.
52. On the Behavior of Becquerel and Röntgen Rays in a magnetic field. R. J. Strutt. *Proc. Roy. Soc.*, lxvi., 75. *Chem. News*, lxxxi., 61, 1900.
53. Radioactive Substances emitted from Thorium Compounds. E. Rutherford. *Phil. Mag.*, V., xlix., 1, 1900.
54. Thermoluminescence durch Radiumstrahlen. E. Wiedemann. *Phys. Zeitschr.*, ii., 269, 1801.
55. Radioactivity of Uranium. W. Crookes. *Chem. News*, lxxxi., 253, 265, 1900.
56. Sur la radio-activité induite, provoquée par les sels de radium. P. Curie and A. Debierne. *Comptes Rendus*, cxxxii., 133, 1901.
57. Sur la radio-activité secondaire des metaux. H. Becquerel. *Comptes Rendus*, cxxxii., 371, 1901.
58. Action physiologique du radium. H. Becquerel and P. Curie. *Comptes Rendus*, cxxxii., 1289, 1901.
59. Sur quelques observations faites avec l'uranium à de tres basses temperatures. H. Becquerel. *Comptes Rendus*, cxxxii., 199, 1901.
60. Sur quelques effets chimiques produits par le rayonnement du radium. H. Becquerel. *Comptes Rendus*, cxxxiii., 709, 1901.
61. The Radioactivity of Matter. H. Becquerel. *Nature*, lxiii., 396, 1901. *Rev. Gen. d. Sci.*, xiii., 603-610.
62. Essais sur quelques reactions chimiques determiné par radium. M. Berthelot. *Comptes Rendus*, cxxxiii., 659, 1901.
63. Sur l'existence de rayons qui subissent la reflexion dans le rayonnement émis par un melange de chlorures de radium et de baryum. Tommasina. *Comptes Rendus*, cxxxiii., 1299, 1901.
64. Die Bedeutung der Becquerelstrahlen, in der Chemie. Baur. *Naturw. Rundschau*, xvi., 338; *Beiblätter*, xxv., 1027, 1901.
65. Radioactivity and atomic weight. Martin. *Chem. News*, lxxxiii., 130, 1901.
66. Methode zur exacten Bestimmung von Ladung und Geschwindigkeit von Becquerelstrahlung. W. Kaufmann. *Phys. Zeitschr.*, ii., 602, 1901.
67. Transparency of Metals and other Substances to Radium Rays. T. Mizuno. *Electrician* (London), xlvi., 399, 1901.
68. Les Corps Radioactifs. P. & S. Curie. *Comptes Rendus*, cxxxiv., 195, 1902.
69. Radioactive Lead. F. Giesel. *Chem. News*, lxxxv., 89, 1902.
70. Ueber radioactives Thor. E. A. Hofmann & F. Zerban. *Ber. Berl. Chem. Ges.*, xxxv., 531. *Chem. News*, lxxxv., 100, 1902.
71. Radioactivity and the electron theory. W. Crookes. *Chem. News*, lxxxv., 109, 1902.
72. The new Gas from Radium. E. Rutherford & Miss Brooks. *Trans. Roy. Soc. Canada*. II., 7, 21. *Chem. News*, lxxxv., 196, 1902.
73. An Investigation of the Radioactive emanations produced by Thorium compounds. E. Rutherford and F. Soddy. *Chem. News*, lxxxv., 55, 1902.
74. Valency and Radioactivity. Martin. *Chem. News*, lxxxv., 310, 1902.

75. Radioactivity, a new property of matter. R. K. Duncan. *Harper's Magazine*, cv., 356, Aug., 1902.
76. Radioactivité dans l'air atmospherique. Geitel. *Arch. des Sciences*, xiii., 113, 1902.
77. Ueber die Wirkung der Becquerelstrahlen auf Bakterien. Aschkinass and Caspari. *Ann. Phys. Chem.* (*Beiblätter*), xxvi., 425.
78. Deviable Rays of Radioactive Substances. E. Rutherford and Grier. *Phil. Mag.*, VI., iv., 315, 1902.
79. The Cause and Nature of Radioactivity. E. Rutherford and F. Soddy. *Phil. Mag.*, VI., iv., 370; VI., iv., 569, 1902.
80. Ueber die radioactive, in Uranpecherz vorkommenden "flüchtige Substanz." Behrendsen. *Phys. Zeitschr.*, iii., 572, 1902.
81. Further experiments on radloactivity from Rain. C. T. R. Wilson. *Proc. Roy. Soc. Camb.*, xii., 17, 1902; xii., 85, 1903.
82. Becquerel Rays. J. J. Thomson. *Harper's Magazine*, cvi., 289, Jan., 1903.
83. Excited Radioactivity and the Method of its Transmission. E. Rutherford. *Phil. Mag.*, VI., v., 95–117, 1903.
84. The Magnetic and Electric Deviation of the easily absorbed Rays from Radium. E. Rutherford. *Phil. Mag.*, VI., v., 177–187, 1903.
85. Sur la Chaleur dégagée spontanément par les sels de Radium. P. Curie and H. Laborde. *Comptes Rendus*, cxxxvi., 673, 1903.
86. Radium. J. J. Thomson. *Nature*, lxvii., 601, 1903.
87. Condensation of the Radioactive Emanations. E. Rutherford and F. Soddy. *Phil. Mag.*, VI., v., 561, 1903.
88. Radioactive Charge. E. Rutherford and F. Soddy. *Phil. Mag.*, VI., v., 576, 1903.
89. The Emanations of Radium. Sir Wm. Crookes. *Proc. Roy. Soc.*, lxxxi., 405, 1903.
90. Sur le rayonnement du polonium et sur le rayonnement secondaire qu'il produit. H. Becquerel. *Comptes Rendus*, cxxxvi., 977, Apr., 1903.

THE CERRILLOS HILLS, NEW MEXICO. (From the northeast.)

THE GEOLOGY OF THE CERRILLOS HILLS, NEW MEXICO.

By DOUGLAS WILSON JOHNSON.

Part I. GENERAL GEOLOGY.

Preface.

The preparation of this paper was first begun when the writer was an assistant on the University Geological Survey of New Mexico, with the intention that it should appear as a reconnoissance report in the bulletins of the Hadley Scientific Laboratories. The work was prompted and supervised by Dr. C. L. Herrick, then President of the Territorial University at Albuquerque, and Director of the Survey. It was found, however, in the course of the brief preliminary investigations then possible, that the field in question presented points worthy of more detailed study than could be given it at that time and permission was granted to withhold the publication of the paper until more satisfactory results could be obtained. The work done at that time represented a few brief excursions to the region during the spring and summer of 1899 and 1900, a portion of the chemical work herein recorded, and some preliminary petrographic examinations.

In the summer of 1902 I again took the field, spending two months in making a detailed study of the Cerrillos region. Maps were prepared, the areal geology worked out with considerable accuracy, and the local conditions affecting the deposits of turquoise, metalliferous veins, and coal seams investigated. Practically all of the palæontological and petrographical work was performed on my return to the laboratories of the Department of Geology of Columbia University.

The area under discussion includes portions of the San Pedro and Santa Clara quadrangles of the United States Geological Survey, the topography being represented by contour lines with intervals of 50 and 100 feet. It was intended to use the required portion of these quadrangles as a basis for the work undertaken, but it soon became apparent that so far as this locality was concerned, the maps were not accurate. As all readings used in working out the areal geology would have to be made on the

monuments which are found on the summits of the various peaks of the Cerrillos Hills, or on other monuments to be established, it was deemed advisable to supplement and correct the topographical sheets in that vicinity by further triangulation. A base-line was accordingly established on the plains northeast of the hills, permitting readings whose angles were sufficiently large to insure accurate results. On the basis of this triangulation the preparation of a more detailed map was possible.

In this connection I was fortunate in securing plots of several detailed surveys, the most important being that of the coal properties of the Colorado Fuel and Iron Company, which covered the whole southwestern portion of the area mapped for this report, and a map of Los Cerrillos Mines covering the central and northern portion of this area. Upon these surveys, checked by the recent triangulation, I have relied for the details of roads, arroyos, etc.

It was also found that the contour lines did not represent the actual physiographic features with accuracy, but the time available would not admit of their extended revision. Accordingly, the contours of the survey have been adopted, with only such changes as seemed necessary to express the true conditions as nearly as practicable. It is only fair to state that the comparatively early date of the topographic work in this locality, and the rather limited size of the area under discussion, in part account for the inaccuracies existing.

While some difficulties were thus encountered at the outset, these were overcome and the work materially assisted in various ways through the hearty interest and coöperation of all to whom I appealed. The Territorial University provided the necessary surveying instruments; the office of the coal mines at Madrid furnished valuable maps; the Cerrillos Smelter officials permitted the use of some of their material; and many others rendered valuable aid.

It is impracticable for me to acknowledge in detail the many sources upon which I have drawn in the preparation of this paper, or to thank personally the many friends who have aided me in the work. On every hand I have met with only courtesy and generous assistance. To the Colorado Fuel and Iron Company and the American Turquoise Company of New York, I am indebted for numerous courtesies extended, especially for the freedom of their mines in the Cerrillos district. Their local superintendents, Mr. Gus J. Johnson and Mr. J. P. McNulty, gave me every possible

assistance. Several of the engravings of views about Madrid and Waldo here reproduced are used through the courtesy of *Camp and Plant*, a publication of the Colorado Fuel and Iron Company. Especial acknowledgments are also due Dr. C. L. Herrick for valuable assistance during the earlier part of the field and laboratory work. Dr. W. G. Tight, president of the University of New Mexico, went over a portion of the field with me, and offered valuable suggestions regarding the physiographic problems involved.

To Mr. Frank Hall Knowlton and Mr. Timothy W. Stanton, of the United States Geological Survey, my thanks are due for courtesies in connection with the palæontological part of the work. Mr. George Steiger made the chemical analysis of the andesite, for which I am indebted to the Geological Survey. Professor N. H. Winchell, of Minneapolis, Professor J. J. Stevenson and Professor Arthur Hollick, of New York, Mr. George F. Kunz, of New York, and Mr. Ed. F. Bennett and others of Cerrillos have extended many courtesies. My companions in the field, Mr. E. Dana Johnson and Dr. O. S. Strong, rendered generous and valuable aid.

Throughout the laboratory and office work which this report entailed, I have profited continually by the advice and suggestions of Professor Amadeus W. Grabau, especially in connection with the palæontological and stratigraphical work. It is also my privilege to acknowledge especial obligations to Professor James Furman Kemp, through whose hearty coöperation the preparation of this paper was made possible. Professor Kemp spent a week with me in reviewing the work in the field, and throughout the office work has been of constant assistance. To the cordial interest and kindly criticisms of Professor Grabau and Professor Kemp this paper owes much of whatever it may contain of value.

INTRODUCTION.

THESIS.

The Cerrillos district, as shown on the geological map and understood in this report, comprises a rectangle eighty square miles in area, and includes the low group of hills generally known as "Los Cerrillos," the towns of Cerrillos, Madrid and Waldo, and the coal fields south of the hills. The area is eight miles in width by ten in length, the northern boundary passing through the cen-

ter of a conical basalt hill known as Mount Calvary, and the western through the point of intersection of the Galisteo Creek with the western base of a low ridge four miles west of the town of Cerrillos, here called the Galisteo monocline.

The present paper aims to give a fairly complete account of the geology of this district. After a brief discussion of the general features, and a synopsis of the work of previous explorers, the general geology of the region is considered. Under this head is presented a detailed discussion of the stratigraphy, followed by an account of the areal geology and physiographic history of the district, and considerations of economic importance. A second part* is devoted to the detailed description of the palæontology of the district, and a third to the petrography.

Among others, the following propositions are supported:

(*a*) The Cerrillos Hills represent laccoliths of andesite intruded in Cretaceous strata after the close of the Cretaceous period.

(*b*) The well-known Santa Fé Marls, of Hayden, are of alluvial origin, and represent the time from the early Loup Fork Tertiary to the Recent period.

(*c*) The Galisteo Group of Hayden consists of red beds of late Cretaceous, probably Laramie age.

(*d*) The coal series, or Madrid Group, is of Fox Hills age.

(*e*) The anthracite and bituminous coal of the above group have been produced from lignite by the metamorphic action of intruded sheets of the andesite.

(*f*) Fort Pierre, Fort Benton, and probably Dakota and Jura-Triassic beds, are also present in the district.

(*g*) The turquoise occurs in altered portions of the andesite, and was formed by heated solutions or vapor rising along lines of fracture in the rock.

(*h*) The basalt flows are of late Tertiary or more recent age.

General Features.

In order that future references may be appreciated the following general relations are here set forth.

Southwest of Santa Fé some twenty-five miles is a group of mountains known as the Gold, Placer or Ortiz Mountains. It is the largest and most prominent of several similar groups. Just

* Part II., Palæontology, appeared in the January number of THE QUARTERLY.

south is the group known as the Tuerto or San Pedro Mountains, while still further southward is the uplift of South Mountain. To the north is the smallest of this series, a group of low conical peaks known as the Cerrillos Hills.

Between the Cerrillos Hills and the Ortiz Mountains to the south, the Galisteo Creek flows westward to join the Rio Grande. Throughout the greater part of the year this creek is a small and insignificant stream, whose waters may become almost stagnant and distinctly saline. In times of heavy rains, however, the stream often rises to the magnitude of a torrential river within a few hours, washing out railroad bridges and otherwise effecting much damage. Numerous arroyos empty into Galisteo Creek, the most important being Coal Gulch and Ortiz Arroyo from the south, and Achavica, Mina del Tiro and San Marcos Arroyos from the north. The creek crosses the Cerrillos quadrangle a little south of the center, extending from southeast to northwest. A small stream known as Alamo, Los Cerrillos or Bonanza Creek, a branch of Santa Fé Creek, flows westward and touches the quadrangle at the north.

Following the north bank of Galisteo Creek is the main line of the Atchison, Topeka and Santa Fé Railroad. Of the three towns within the district, two — Los Cerrillos (or simply Cerrillos) and Waldo — are situated on the railroad. The mining town of Madrid is about two miles south of Cerrillos, and is connected by a branch railroad with the main line at Waldo. On the northern boundary of the quadrangle is the little Mexican village of Bonanza, on Bonanza Creek, while ruins of small mining settlements are to be found near here, and also at Carbonateville east of Mount McKensie, and at Rogers, south of Waldo. In earlier days considerable coal was mined at Rogers, and a branch railroad connected the town with the main line at Waldo. The water supply for the three larger towns is secured from a reservoir built in San Marcos Arroyo, about two miles and a half northeast of Cerrillos, to catch the water flowing underground in the arroyo at this point.

The Cerrillos Hills (Plate A) consist of six low, conical peaks, rising rather abruptly from the surrounding level. Several of these peaks have a low saddle at the apex, thus giving them double summits. This is the case with the hills known as Grand Central Mountain, Achavica Mountain, and Santa Rosita Mountain. The remaining hills, Mount McKensie, Santa Rosa Mountain and Lueras

Hill are somewhat more elongated than their neighbors.* Just east of Grand Central Mountain is a low hill known as Mount Chalchihuitl (Plate M). Here are located the famous mines for turquoise, the "chalchihuitl" of the ancient Mexicans.

The above make up the group of the Cerrillos Hills proper, but included in the district are several minor hills. The most striking of these is Mount Calvary (Plate I), a couple of miles due north of the main group. It is a conical hill of basalt, very symmetrical, and of striking appearance. Just east of it is the irregular uplift known as Bonanza Hill. Northwest of the main hills is a low volcanic crater (Plate H), from which a sheet of basalt has flowed out over the surrounding plain; while to the northeast are three small hills which appear more prominent because of their isolated positions. The most important of these is popularly called Turquoise Hill, (Plate O) as the mines of the American Turquoise Company of New York are located there. One mile to the southeast is a low conical hill called Middle Hill, on account of its position between Turquoise Hill and the third member of this trio, still farther southeast, which is called Rocky Butte (Plate L). Northeast of these hills the unbroken plains slope gradually up to the base of the Santa Fé Mountains, one of the loftiest ranges in the territory, while south of the Galisteo a smaller plain slopes upward to the base of the Ortiz group. To the southwest is the great monoclinal uplift of the Sandia Mountains.

The Galisteo Creek and its tributary arroyos have dissected the general plain level to such an extent in the central and southern part of the Cerrillos district, that the country appears quite rough and broken. But one of the most striking features of the region is formed by the remnants of the old plain. Even as one stands in the valley of the Galisteo one is impressed with the uniform level of the hills which form the sides of the valley, especially to the south. When the observer ascends to the top of one of these low hills, he is surprised to find himself looking out over a dissected plain, which slopes gradually upward to the neighboring mountains. Near Madrid this plain is interrupted by a series of monoclinal uplifts which project above the general level. It is

* The above, and other names, as well as the spelling, are based on old and recent maps, the statements of local residents, and other sources. In almost every instance such evidence was conflicting. I have endeavered to employ the names and spelling which seemed to be most in use at present.

Santa Rosa Mt. Achavica Mt.
Lueras Hill. Grand Central Mt.

THE CERRILLOS HILLS, NEW MEXICO. (Looking north through Coal Gulch.)

evident that the Galisteo and its tributaries have cut their valleys into the gently sloping plain formed by confluent alluvial fans from the surrounding mountains. In some cases portions of this plain have been completely cut off from the main mass, and stand as isolated mesas out in broad valleys, closely resembling the phenomena observed in a dissected peneplain. In fact, as we shall see, the conditions here are those of an alluvial plain formed upon an erosion plain, and both subsequently dissected by erosion. The result of the above processes is well shown in Plate C, reproduced from a photograph of the sides of the Galisteo valley just south of the Hills.

Cerrillos (Plates C and K) is the main railroad center for the district, and is the largest town. A modern smelter has recently been built to treat the lead, silver, gold and copper ores from the small mines in the Cerrillos Hills, as well as ores shipped in from more distant points. Madrid (Plate D) is the southern terminus of the Cerrillos Coal Railroad, a small branch which connects with the main line of the Atchison, Topeka and Santa Fé Railroad, three miles north. It is a small mining town of about 1,000 inhabitants, and is the center of the coal industry of the district. The offices, works and coal mines of the Colorado Fuel and Iron Company are located here. The coke ovens are located at Waldo (Plate D), a small village about three miles north of Madrid, at the junction of the Cerrillos Coal Railroad with the Santa Fé main line. In the fifty bee-hive coke ovens a part of the product of the coal mines at Madrid is reduced to coke. The office of the local superintendent of the turquoise properties is located at the mines at Turquoise Hill, the old mines at Mt. Chalchihuitl being no longer worked.

Earlier Reports.

The Cerrillos district has long claimed the attention of geologists and other explorers, and plays a not unimportant part in the geological literature of this region. The placer gold mines of the Ortiz Mountains were the most important factor in calling attention to this immediate locality, while the anthracite coal of the Madrid field has become prominent in later years. The silver, gold, lead and zinc mines of the Cerrillos Hills have been of interest, while the turquoise deposits have made the locality famous both at home and abroad. The district also forms a part of the type locality of the Santa Fé Marls of Hayden, which have an impor-

tant place in the literature of the early surveys. It would be impossible to collect all the many scattered references to this region and its interesting geological phenomena, but a brief résumé of the more important work is presented below.

The earliest workers in the mines of this region belonged to an ancient race of Indians, of whose history we know little. When the earliest white explorers entered the region they found the extensive turquoise mines of Mt. Chalchihuitl long abandoned, and large cedar and piñon trees growing over the dumps, and down in the diggings. The vast extent and the evident antiquity of the workings were marvellous. The stone hammers of these ancient miners are still to be picked up amongst the débris. As the mines have never been worked to any extent since the Pueblo uprising in 1680, practically all of the vast excavation must have been made prior to that date, and must represent a very great length of time.

The earlier explorers also found that the lead, silver and other mines in the Cerrillos Hills had been worked to a greater or less extent, while the placer mines to the south were still in operation and a few settlers were carrying on gold mining in a more extensive manner. It is, however, in the scientific work of the various exploring expeditions that we are most interested.*

In July, 1846, Dr. A. Wislizenus visited the Cerrillos district, while on a scientific tour to Mexico. He made a careful study of the placer mines in the Ortiz Mountains to the south, and in his report † describes these workings in detail and mentions a few other points of general geological interest.

In September, of the same year, Lieut. J. W. Abert made a trip from Santa Fé to the placer mines in the Ortiz Mountains, while connected with the Army of the West. Lieut. Abert describes ‡ the placer mines, and gives notes concerning the eruptives and sedimentaries of the Cerrillos region, the occurrence of coal and other points of interest.

Major W. H. Emory visited the region in 1846, in connection

* A more extensive résumé of the work of some of the writers now to be cited may be found in Prof. J. J. Stevenson's report to Lieut. Wheeler, U. S. Geog. Surv. West of 100th Mer., Vol. III., Supplement, pp. 28–36. A still more detailed account appears in connection with the discussion of the various geological problems, in subsequent pages.

† Senate Miscellaneous Document No. 26, 30th Congress, 1st Session.

‡ Senate Executive Document No. 23, 30th Congress, 1st Session.

with the Advanced Guard of the Army of the West. His report * contains but few notes on the Cerrillos district.

In the fall of 1853 Prof. Jules Marcou, in connection with Lieut. Whipple's exploration for a railway route near the thirty-fifth parallel, made more extensive notes on the geology of the Cerrillos district. He describes † the alluvial deposits washed down from the neighboring mountains, the sedimentary rocks, the eruptives, and the numerous dikes which are so prominent a feature of the region.

In 1857 Prof. William P. Blake visited the Hills, and published notes on the geology ‡ and mineral resources § and a paper on the turquoise deposits ||.

In 1858 Prof. J. S. Newberry, in connection with the Ives Exploring Expedition, visited the Cerrillos district and made some general notes on the geology.** A year later Prof. Newberry again had the opportunity to visit this region, while connected with the Macomb Exploring Expedition. At this time he made a much more extended study of the geology, and his report †† on the area was the most extensive we had up to the time of its publication. Prof. Newberry discussed the character and age of the various deposits, the occurrence of the anthracite coal, iron, placer gold, and other mineral products, and the types and age of the eruptive rocks.

Dr. John L. Le Conte, in connection with the survey of the Union Pacific Railway, visited the region in 1867, and made some observations upon the geological conditions. In his report ‡‡ he

* Executive Document No. 41, 30th Congress, 1st Session.

† "Explorations and Surveys for a Railroad Route from the Mississippi River to the Pacific Ocean," Vol. III., Pt. IV., No. 2, pp. 140–141.

‡ "Observations on the Geology of the Rocky Mountain Chain in the Vicinity of Santa Fé, New Mexico," *Proc. A. A. A. Sci.*, 1859, pp. 314–319.

§ "Observations on the Mineral Resources of the Rocky Mountain Chain near Santa Fé, New Mexico," *Proc. Bost. Soc. Nat. Hist.*, 1859, pp. 64–70.

|| "The Chalchihuitl of the Ancient Mexicans," *Am. Jour. Sci.*, Vol. XXV., 1858, pp. 227–232.

** "Report upon the Colorado River of the West," by Lieut. J. C. Ives, Wash., 1861. Pt. III., Geol. Report, pp. 98–99.

†† "Report of the Exploring Expedition from Santa Fé, New Mexico, to the Junction of the Grand and Green Rivers," by Capt. J. N. Macomb, 1859. Geol. Report, pp. 38–42.

‡‡ "Notes on the Geology of the Survey for the Extension of the Union Pacific Railway, E. D., from the Smoky Hill River, Kansas, to the Rio Grande;" Phila., 1868, pp. 36–41.

mentions the occurrence of the coal, placer gold, turquoise and other valuable products, discusses the origin of the anthracite and the character of the eruptives. A section through the coal series and other details are given.

In 1869 Dr. F. V. Hayden made a reconnoissance "from Santa Fé to Placiére Mountains and return." His report * is brief but of unusual interest and value. He describes and names the group known as the Santa Fé Marls, and the Galisteo Group of red sandstones. The occurrence of the coal is discussed, detailed sections given, and the mineral products described. In other portions of this same report are points of interest which bear on this special region.

Dr. Oscar Loew connected with the Wheeler Expedition, visited the region in 1874, and his reports † record several observations upon the geology of the Cerrillos district.

During the same year Prof. E. D. Cope, also connected with Lieut. Wheeler's Expedition, made a trip through this region and published notes concerning the Santa Fé Marls and older deposits.‡ The greater part of Prof. Cope's observations were made at points outside of the Cerrillos district proper, but have a direct bearing on geological problems involved in the study of that area.

In 1878–79 Prof. John J. Stevenson, in connection with the Wheeler Survey, made a study of the geology of southern Colorado and northern New Mexico. His report § gives the most extensive account yet published of the geology of the region about Galisteo and from there westward to the Cerrillos district. The details of Prof. Stevenson's observations are considered more fully in subsequent pages.

In 1880 Prof. Benjamin Silliman visited the Cerrillos Hills, and published notes on the "Turquoise of New Mexico." ‖ He dis-

* "Preliminary Field Report of the United States Geological Survey of Colorado and New Mexico, 1869," pp. 66–68.

† "U. S. Geog. Surv. West of 100th Mer.," Vol. III., Pt. VI.; also Rep. of Chief of Engineers, 1875, Pt. II., Appendix G 2.

‡ "U. S. Geog. Surv. West of 100th Mer.," Vol. IV., Pt. II.; *Proc. Phil. Acad. Nat. Sci.*, 1874, pp. 147–152; same for 1875, p. 271; also Rep. of Chief of Engineers, 1875, Pt. II., Appendix G 1.

§ "U. S. Geog. Surv. West of 100th Meridian," Vol. III., Supplement.

‖ *Am. Jour. Sci.*, July, 1881, pp. 67–71.

TOWN OF CERRILLOS. ORTIZ MOUNTAINS IN DISTANCE. (Showing dissected alluvial plain.)

cusses the age of the Cerrillos uplift, the occurrence of turquoise, and the extent and antiquity of the mines.

Prof. Stevenson again visited the Cerrillos district in 1895, and published extensive notes on the occurrence and origin of the anthracite coal,* together with considerations of the local geology.

In 1897 Dr. C. L. Herrick studied the Cerrillos district, and briefly described † some of the general geologic features.

The work of the writer represents several excursions into the region during the spring and summer of 1899 and 1900, and a more extensive and detailed study during the summer of 1902. The results of the studies are herewith presented.

STRATIGRAPHY.

The Santa Fé Marl Group.

Loup Fork Tertiary to Recent.

Throughout the Cerrillos district, except where the Galisteo Creek and its tributary arroyos have removed them, a series of horizontally bedded marls, marly sands and conglomerates are found resting upon the planed-off edges of the upturned older sediments. To this series Dr. Hayden gave the name "Santa Fé Marl Group," and its interest to geologists has always been considerable. Its deposits constituted the basis for one of the great Tertiary lakes assumed by the geologists of our early surveys to have occupied so much of the area of the western territories during the Tertiary period. At a time when we are just beginning to realize that some of these supposed lacustrine deposits are really of fluviatile or alluvial origin, a study of the Santa Fé Marls proves especially interesting.

So far as I am aware, the first notes on the Santa Fé Marls were made by Jules Marcou in the fall of 1853. In his field-notes for October 1 and 2 of that year,‡ he speaks of a "diluvium coming from Gold (Ortiz) Mountain"; "hills of diluvium (in the village of Galisteo) coming from the Santa Fé Mountains" and containing "masses of granite, serpentine, etc.;" "the thick diluvium containing angular fragments of small size, and mingled with sand

* *Trans. N. Y. Acad. Sci.*, January, 1896, pp. 105–122.

† *Bull. Univ. New Mexico*, Vol. I., pp. 109–114.

‡ "Exploration and Survey for a Railroad Route from the Mississippi River to the Pacific Ocean," Vol. III., Wash., 1856; Pt. IV., No. 2, pp. 140–141.

and rose-colored granite, with crystals of hornblende;" and of "a whitish conglomerate, in horizontal beds, covering the trachytes along the creek."

In 1858 Prof. Newberry, on his first trip to this region, noted that the only rock visible from the Cerrillos Hills to Santa Fé was red calcareous sandstone of the Marl series (Triassic) which is generally covered by "drift from adjacent mountains."* In 1859, on his second trip, Prof. Newberry made a much more extensive examination of this region, but in his report does not discuss the Santa Fé Marls. In one place he says:† "It is only near the Rio Grande that the Tertiary beds to which I have referred make their appearance." Evidently, then, he did not consider the Santa Fé Marls which are so well exposed in the Cerrillos region and from there to Santa Fé as belonging to the Tertiary. It would seem that he regarded these beds as recent drift derived from neighboring mountains, and not worthy of more than passing notice.

In 1869 Dr. Hayden visited the Cerrillos district, investigating and naming the deposits known as the Santa Fé Marls. In his preliminary report on the field work for that year he says:‡ "From Santa Fé to the banks of the Galisteo Creek, eighteen miles, we pass over the recent marls and sands which seem to occupy the greater portion of the valley of the Rio Grande, above and below Santa Fé, and which I have called Santa Fé marls. These are mostly of a light cream-color, sometimes rusty yellow, and sometimes yellowish-white, with layers of sandstones, varying in texture from a very fine aggregate of quartz to a moderately coarse pudding-stone. These marls and sands weather into unique forms north of Santa Fé, like the 'bad lands' or 'Mauvais terres' of Dakota." A little further on we find the statement "basaltic rocks are poured over the recent Tertiary beds," and finally "We have, therefore, in the valley of the Rio Grande, if my investigations are correct, three groups of Tertiary beds of different ages: (1) The coal strata; * * * (2) the Galisteo sand group; * * * (3) the Santa Fé marls, which are of much later date than either of the other two, and rest unconformably upon the Galisteo group, and never in-

* "Rep. upon Col. Riv. of the West," by Lieut. J. C. Ives, Wash., 1861; Pt. III., pp. 98–99.

† "Rep. of the Expl. Exped. from Santa Fé, N. M., to Junct. of Grand and Green Riv.," by Capt. J. N. Macomb, 1859; Geol. Rep., pp. 38–42.

‡ "Prelim. Field Rep. U. S. Geol. Surv. of Col. and New Mex.," pp. 66–68, 1869.

cline more than five or ten degrees." In the report of a trip from Santa Fé to Taos* we find the following: "These Santa Fé marls reach a great thickness north of Santa Fé, in the Rio Grande valley, from one thousand two hundred to one thousand five hundred feet, and have a tendency to weather into similar monumental and castellated forms, as in the 'Bad Lands.' The upper portions are yellow and cream-colored sandstones, sands and marls. Lower down are some gray coarse sand beds with layers of sandstone. All these marls dip from the range westward three to five degrees. The Rio Grande wears its way through these marls with a bottom about two miles wide. * * * As we go northward near the mountains, the rounded boulders become more and more numerous, but near the Rio Grande, where they have all disappeared, the source of this great thickness of sediment is apparent." And in another place,† "Along the base of the mountains, especially in the valley of the Peñasco, there is a great thickness of very coarse conglomerate resting upon the granite horizontally. It is undoubtedly of the same age as the marl beds." In other places Dr. Hayden frequently refers to the fact that these marls are overlain by basalt.

I have quoted thus extensively from Dr. Hayden's report in order that we may clearly understand the essential relations and characters of the Santa Fé Marls as understood by the one who defined and named them. We see from his statements that the following facts hold true in the type locality:

1. The beds vary greatly in thickness.

2. They vary greatly in composition in vertical section, showing marls, fine and coarse sands, and fairly coarse pudding-stones.

3. They vary greatly in composition in areal distribution, and have a tendency to consist of great beds of coarse conglomerates near the mountains, to become finer and finer farther away from the uplift, and to consist of fine sediments at the more remote localities.

4. They dip with a small but comparatively uniform inclination in all directions from the mountains.

5. They rest unconformably upon the upturned sandstones of the Galisteo Group, east of Cerrillos.

6. They are overlain by basalt flows in a number of places.

It is with the above points as a standard of comparison that I

* *Ibid.*, p. 69.

† *Ibid.*, p. 70.

wish to review the opinions of other geologists regarding these beds.

In 1874 Professor E. D. Cope visited this region, and later in that same year published a paper entitled "Notes on the Santa Fé Marls and Some of the Contained Vertebrate Fossils." * A still more extensive account † of these beds appeared in Professor Cope's full report to Lieut. Wheeler.

Professor Cope confined himself largely to a discussion of the vertebrate remains and the age of the beds. He considered these Marls of lacustrine origin, and referred them to the Loup Fork epoch, on the basis of vertebrate fossils obtained near San Ildefonso, Sante Fé and Santa Cruz.

In 1879 Professor J. J. Stevenson, in connection with the Wheeler Survey, studied this region, and published "Notes on the Geology of Galisteo Creek, New Mexico" ‡ in which he described the beds in question. These notes appeared more fully §in Professor Stevenson's report to Lieut G. M. Wheeler upon the "Geological Examinations in Southern Colorado and Northern New Mexico, During the Years 1878 and 1879," from which report I note the following:

Professor Stevenson divided these horizontal beds into two different groups, which he considered of different ages — the Galisteo Group being "not older than early Miocene or newer than early Pliocene," and the Santa Fé Marls, belonging, as determined by Cope, to the Loup River epoch of the Pliocene. It is unfortunate that the name "Galisteo Group," which had already been employed by Dr. Hayden to denote the easterly dripping red sandstones above the Coal Measures, should be applied to an entirely different series of beds at the same point. I cannot see that the possibility of the red sandstone series belonging to the Laramie or coal group forms any objection to the use of a local term to designate a special development of a part of such group, and in my treatment of this region can only adopt the terms established by Hayden in 1869.

Professor Stevenson gives the following section of his so-called Galisteo Group:

---

* *Proc. Phil. Acad. Nat. Sci.*, 1874, pp. 147–152, pls. IX.–XI.

† U. S. Geog. Surv. West of 100th Mer., Vol. IV. Pt., II., pp. 20–25.

‡ *Am. Jour. Sci.*, Vol. XVIII., pp. 471–475, 1879.

§ U. S. Geog. Surv. West of 100th Mer., Vol. III., Supplement, pp. 159–163, 1881.

From "Camp and Plant."

Madrid, New Mexico. On the right the uniform level of the dissected plain is shown, while the Cerrillos Hills appear in the background at the left.

From "Camp and Plant."

Coke Ovens at Waldo, New Mexico.

	Feet.
Trachyte breccia	150
Soft light gray sandstone	40

The breccia is described as "very dark gray or even lead colored, and is composed of angular fragments, cemented by finer material, apparently of similar nature." The sandstone is "very light gray, excessively soft and incoherent, so that it yields to the weather as though it were loose sand, weathering, indeed, more freely than do the tough alluvial deposits along the creeks. This is the lowest bed of the group found within the area examined." Regarding the relation of these beds to each other and to the underlying beds, Professor Stevenson says: "Both the breccia and the underlying sandstone (of the above group) * * * are conformable. * * * The breccia is composed largely of trachyte from Los Cerrillos, a group of trachyte hills shown on the north side of Galisteo Creek at sixteen miles below the village (Galisteo). But the outburst of trachyte, forming those hills, caused frightful contortion of the Laramie beds (Galisteo Group proper, of Hayden). It is clear, then, that the Galisteo Group (of Stevenson) cannot be conformable to the Laramie. * * * It certainly antedates the great flow of basalt, for as far as examined it shows no included fragments of that rock. It no doubt is long posterior to the trachyte outburst, for it rests on the leveled edges of the rocks which were turned up during that outburst."

On reading Professor Stevenson's account of this Group it readily becomes apparent that it is none other than the typical Santa Fé Marls of Dr. Hayden. And, as I shall show in subsequent pages, the examination of the beds in the field confirms this fact. For the present I will merely compare Professor Stevenson's description of the beds with the standard of comparison which we have in Dr. Hayden's report. Reference to that standard (p. 315) will show that so far as the composition of the beds is concerned, there is nothing in Professor Stevenson's description which does not agree with that of Dr. Hayden's as shown in paragraph No. 2. This group, according to Professor Stevenson, rests unconformably upon the upturned edges of the sandstones (Laramie of Stevenson, or Galisteo Group of Hayden) east of Cerrillos. The Santa Fé Marls, in their typical development, occupy exactly this position with relation to these same beds in the same locality as noted in paragraph No. 5. Professor Stevenson states that this group is older than the basalt

flows. Dr. Hayden states clearly that the Santa Fé Marls are older than the basalt flows, being overlain by such flows in a number of places (paragraph No. 6). There can be no doubt, then, that the so-called Galisteo Group of Stevenson is nothing else than the Santa Fé Marl group of Dr. Hayden.

Professor Stevenson then describes what he considers as the Santa Fé Marls, and gives the following section:

	Feet.
Silt	1
White marly limestone	1
Conglomerate	3
Clay	10
White marly limestone	3
Total	18

He further says*: "The marly or chalky limestone is present beyond Galisteo Creek southward on the bench reaching toward the Placer Mountain, and very possibly the whole of the loose material seen there, consisting of fragments of trachyte, granite, etc., with sands, clays, and irregular layers of the marly limestone, may be included in this group (Santa Fé Marls); the thickness being between fifty and seventy-five feet. * * * The group is certainly newer than the basalt, for fragments of that rock cemented by it occur on the Ocate Mesa near the Wagon Mound. It overlies the basalt in the Upper Valley of the Rio Grande."

It is evident that the tabulated section given above is merely a small fraction of the upper part of the Santa Fé Marls. As for the beds beyond the Galisteo Creek southward on the bench reaching toward the Placer Mountain, after a careful examination of numerous exposures, I am convinced that they are absolutely identical and were once continuous with the beds on the north side of the creek, that they are older than the basalt, being overlain by it further north, and that they rest directly on the leveled edges of the upturned yellow and red sandstones of the Galisteo Group proper, as well as of the earlier Cretaceous rocks. It will be seen that the very uppermost few feet (alone) of the Santa Fé Marls are more recent than the basalt and overlie it in places; or, in other words, that the whole of the Santa Fé Marls constitute a single, practically indivisible formation; that after a large part of the beds had been deposited the basalt was poured out over the beds already

* *Ibid.*, p. 162.

formed; and that this basalt was in turn covered in places by the small amount of marls which continued to be deposited after the eruption.

One fact which led Professor Stevenson to separate the upper few feet of these Marls from his so-called Galisteo Group, was the evidence, at a certain point, of unconformity between the two. Believing, as the earlier geologists did, in the lacustrine origin of these beds, such a conclusion was most natural. When the true character of these deposits is understood, however, it will be seen that such unconformities are very numerous and bear no relation to the age of the beds, but rather to the mode of their formation.

Both Dr. Hayden and Professor Stevenson refer in several places to a peculiar conglomerate or breccia cemented by carbonate of lime, and which in some instances they considered of Recent or Quaternary age. As will appear later, such a deposit is characteristic of the Santa Fé Marls at many points in the type locality.

In 1897 Dr. C. L. Herrick visited this region and published notes on "The Geology of the Cerrillos and Ortiz Area." * After speaking of the Cretaceous shales, he says: "Above these shales is a bed of crag and loose material over 50 ft. thick. The boulders at the bottom of this series are of phonolite similar to that of the mountains at the south end of the range (Cerrillos). The whole is capped by 25 ft. of recent lava from the adjacent cone." Dr. Herrick does not refer to the origin of these beds further than to state his opinion that they resulted from the erosion of the Cerrillos hills. He speaks of them as "perhaps Pleistocene," and apparently did not recognize their identity with the Santa Fe Marls of Hayden.

In the summer of 1902 the writer made a careful study of the Santa Fé Marls, which are typically developed in the Cerrillos district, although not attaining the great thickness reported from farther north. The locality east of Cerrillos, studied by Dr. Hayden, and many other excellent exposures, were visited, and some interesting data collected.

As shown on the map, the Santa Fé Marls cover a large portion of the Cerrillos district. Before the present erosion cycle, these marls extended over the entire area, and were the only sediments visible, with the possible exception of the uptilted coal measures

* *Bull. Univ. New Mex.*, Vol. I., pp. 109–114.

at Madrid, which may have protruded a short distance above their surface. The andesite peaks of the Cerrillos Hills doubtless still projected above the surrounding blanket, which they had helped to form by contributing a goodly supply of material for the conglomeritic and finer beds. It was the more recent erosion which revealed the underlying Cretaceous, and to-day we find these older rocks exposed in the valleys of the river and tributary arroyos, while the Marls still cover the general level into which these valleys have been cut.

The relation of the Santa Fé Marls to the underlying rocks is clearly shown in a number of places, one of the best being a mile or two east of the town of Cerrillos (Plate G). The red and yellow sandstones of the Galisteo and Madrid groups, upturned by the Cerrillos intrusion, have been leveled off, and the practically horizontal Marl beds deposited upon them. One mile west of Madrid these Marls rest horizontally upon the upturned and planed-off edges of the Fort Pierre beds in exactly the same manner, while the same relation to Fox Hills and Colorado beds is seen at several points. The extreme regularity of the rock floor upon which these Marls were deposited is remarkable, and its significance is considered elsewhere.

The relation of the Santa Fé Marls to the basalt flow is well shown west of the Cerrillos Hills (Plate F). Here the Marls consist of some 20 to 30 ft. of conglomerate, above which are pink marls and sands of considerable thickness, the whole being capped by 10 ft. of olivine basalt. There is no evidence of any great erosion unconformity between the Marls and the basalt, while farther north the eastern side of the flow is concealed by a small amount of marls apparently identical with the Santa Fé Marls below, of which they doubtless form a continuous part.

The accompanying diagram (Fig. 1) will serve to illustrate the existing conditions:

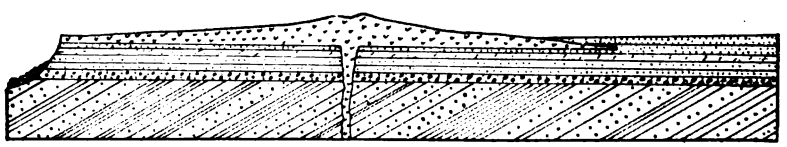
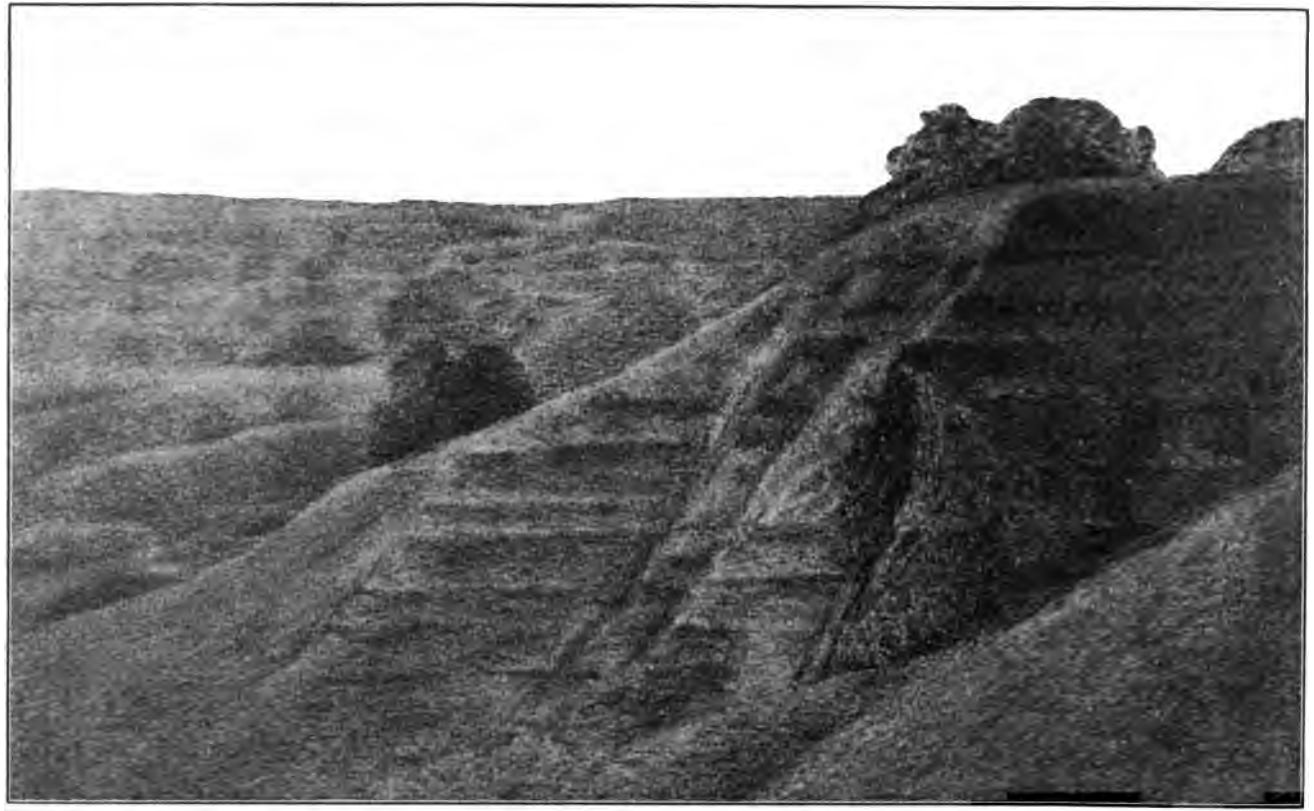


FIG. 1. Diagrammatic illustration of the relations of the Santa Fé Marls to the basalt flow and to the underlying Cretaceous beds. (Latter should dip east at the left of figure.)



DRAWN FROM PHOTOGRAPH, BY R. B. JOHNSON.

SANTA FÉ MARLS. (Showing weathering effects in the softer beds.)

Wherever seen, the Marls consist of beds of a peculiar conglomerate of more or less coarse andesite fragments cemented by a marly cement; of beds of very fine, soft marls and sandstones; and of coarser sands. Frequently the finest sands and marls are mixed with coarse pebbles or boulders. In the peculiar conglomerate above mentioned the fragments are not rounded, showing that the material was not transported far. The local character of the formation is also indicated by the fact that nearly all of the fragments are of the same rock composing the Cerrillos Hills and Ortiz Mountains. In some of the higher beds are often found well rounded, worn pebbles and boulders of red granite, mica schist, etc., which must have had their source in the Santa Fé Mountains 20 to 25 miles northeast of the district.

Although possible, it does not seem to me at all probable that these Marls were ever much thicker in the Cerrillos district than they now are. The greatest thickness I have seen is a little less than 100 feet, although a short distance northeast of the area under discussion a thickness of about 200 feet is found. In other localities, especially nearer the large mountain ranges, a much greater development of these beds is noted.

Origin.

Concerning the origin of the Santa Fé Marls the earlier geologists apparently entertained two different opinions. Although their belief is not definitely stated, we may infer from the notes of Marcou and Newberry that they considered these beds to be wash from the adjacent mountains deposited by subaërial action. Marcou speaks of "thick diluvium coming from the Gold and Santa Fé Mountains," while Newberry calls it "drift from adjacent mountains."

On the contrary, Hayden and Cope regarded these beds as having been deposited in a great Tertiary lake occupying the region between the Santa Fé Mountains on the east, the Cochiti range on the west, and extending an unknown distance southward. Hayden stated his belief in a lacustrine origin for these Marls in the following words.* "I have already alluded to my belief that this western country during the Tertiary period was covered to a greater or less extent with a chain of brackish or fresh-water lakes; that the Tertiary period began its existence with brackish water deposits,

* Prelim. Field Rep. U. S. Geol. Surv. of Col. and N. Mex., pp. 89-90, 1869.

which gradually became fresh water, and thus continued up to the present time." He then states that he divides these lacustrine deposits into lower, middle and upper Tertiary, describes the lower and middle Tertiary beds, and continues: "In the valley of the Rio Grande at least from Albuquerque to the north end of San Luis Valley, a series of marly sands of a light color prevail to a greater or less extent. * * * To this group I have given the name of Santa Fé marls; and they are doubtless of the age of upper Tertiary."

That Professor Cope believed in a lacustrine origin for these beds there can be no doubt. He repeatedly refers to them as "lacustrine deposits." This belief was not unqualified, however, for in speaking of the fauna of the Santa Fé Marls, Professor Cope himself calls attention * to the noteworthy absence of fish and crocodile remains, describes the occurrence of "numerous vertical streaks, or rods, of a white calcareous mineral" resembling "tubes formed by the decay of roots of a marsh vegetation, or by the borings of mud-loving animals," and suggests that these Marls may have been formed in a marsh rather than a lake. That his belief in a lacustrine origin was still predominant, however, is evidenced by his continued references to the lacustrine conditions he considered to have then prevailed. In the same report with the above, he says: † "These beds (Triassic) crop out in high bluffs, and doubtless formed the precipitous western shore of the fresh lake which, during the Loup Fork epoch, filled the valley of the Rio Grande from its upper waters to an unknown distance toward Mexico." And again, "The earliest information which we possess respecting the existence of Vertebrate remains in the lacustrine deposits of the Rio Grande Valley," etc.

So far as I am aware Professor Stevenson has not expressed himself directly regarding his opinion of the origin of the Santa Fé Marls. In his report to Captain Wheeler, ‡ however, he says: "Here and there on the plain (Canadian) a marly, travertine-like limestone underlies the Quaternary, and probably marks the place of some later tertiary lakes." In the index to the supplement this deposit is included under "Santa Fé Marls."

A detailed study of the various exposures of the Santa Fé Marls

* U. S. Geog. Surv. West of 100th Mer., Vol. IV., Pt. II., p. 361.

† *Ibid.*, p. 24.

‡ U. S. Geog. Surv. West of 100th Mer., Vol. III., Supplement, p. 225.

in the Cerrillos region convinced me that these beds are of alluvial, and not lacustrine, origin. I believe they are wholly the result of laterally confluent alluvial fans spreading out from the Santa Fé, Cerrillos, Ortiz and neighboring ranges, and composed entirely of the débris eroded from those ranges and deposited by subaërial agencies. I do not believe that any Tertiary or more recent lake of noteworthy dimensions ever occupied this region, or materially affected the alluvial deposits.

Before considering the evidence furnished by the data collected, I desire to review the criteria which may be used in discriminating

FIG. 2. Santa Fé Marls as exposed in San Marcos Arroyo, east of Cerrillos Hills.

between deposits of alluvial and lacustrine origin. In a paper on "The Freshwater Tertiary Formations of the Rocky Mountain Region," * Professor W. M. Davis has called attention to the almost universal interpretation of fresh-water strata as lake deposits by the geologists of our western surveys, has noted the existence in many localities of fresh-water strata which are undoubtedly the result of laterally confluent alluvial fans, and has expressed his belief

* Proc. Am. Acad. Arts and Sci., Vol. XXXV., No. 17; pp. 345–373. March, 1900.

that a part of the so-called lake-deposits of Tertiary age are really deposits of the latter nature. Professor Davis described at some length the essential characters of both lacustrine and subaërial deposits, some of which are practically those noted below.

In a large and comparatively deep lake, such as that assumed by the earlier geologists to exist in this region, we should expect the marginal deposits to be more or less coarse and irregular, while the deposits over the central floor of the lake would be of very fine and even texture. That such must be the conditions is shown by the study of existing lakes. No extensive variations in texture or composition would be possible in this central portion. We cannot conceive that either waves or currents could sweep coarse pebbles or boulders far out into such a lake, and so give us layers of conglomerate alternating with fine sands, marls, etc. Such conglomerates could only appear near the shore line. Even coarse sands could not be present alternating with fine marls, etc. As Davis says: "It can hardly be imagined that the sediments deposited on the floor of a large lake should contain frequent alternations of finer and coarser beds, such as clays and sands." On the other hand, in deposits formed by laterally confluent fans of waste, deposited by subaërial agencies, such variations are to be expected. Although in general the coarser débris would be dropped nearer the mouths of the various cañons, and the finer material carried further out, still with the growth of the fans, and the varying conditions due to floods of greater or less extent, changes of season, etc., material of considerable coarseness as well as the finer débris would be carried far out from the mountains. Consequently we should not be surprised to find conglomerates of fair sized pebbles at a considerable distance from the mountains often alternating with fine sands and marls. These variations would be further complicated by the interlocking of different fans laterally, or of fans from different mountain ranges.

In deposits formed on the floor of a large lake we should not expect to find sudden marked variations in the thickness and areal extent of the component beds. This would be especially true of the deposits in the central portion of such a lake, where a considerable degree of uniformity of thickness and extent would necessarily exist. The stratification would be fairly evenly developed, and it would be difficult to conceive of beds of sandstone several feet in thickness suddenly wedging out and disappearing entirely

to be replaced by wholly different strata. In alluvial fans, however, such occurrences would be most natural, and while a remarkable degree of perfection in the stratification of the finer deposits of such fans has been noted, instances of the sudden "wedging out" of beds are still more numerous, especially in the coarser deposits. As a necessary corollary, the component layers in lacustrine deposits could vary but little, while those of alluvial deposits might vary greatly, within a limited area.

In lacustrine deposits there would be little or no development of erosion unconformities. It is evident that under normal conditions there would be no opportunity for streams to cut channels in the finer sediments, and then fill these channels with gravel or sand brought from distant sources. In alluvial fans, however, such phenomena would necessarily occur to a greater or less extent. Streams flowing out over the fan, constantly cutting and refilling new channels, and washing boulders and gravel along channels cut in the finest marls or sands, would leave their records in the shape of numerous unconformities of erosion. Such evidence might not always be available, but where it did appear in a marked degree would be undoubted evidence of the subaërial origin of the deposits.

Abundant cross-bedding at high angles would not be expected in deposits on the central portion of a large lake floor, but would be very natural in the sands of alluvial cones, where the changing streams would develop the phenomena to a marked extent.

A land fauna or flora, with entire absence of fish remains, would be strongly suggestive of a subaërial origin for the deposits enclosing them, rather than a lacustrine origin.

The Cerrillos district occupies a somewhat central position in the area supposed to have been covered by the great Tertiary lake of the earlier geologists. It is at least some ten or fifteen miles from the eastern "shore line" of that lake, and a like distance from the western shore; while to the north and south the lake extended for much greater distances. The small group of the Cerrillos Hills could not have materially affected the deposits of that central area, as they would have been buried beneath the waters of the lake, the deposits occurring elsewhere a number of feet higher than the highest of the Cerrillos peaks. Any other hypothesis would necessitate an extensive subsidence since the deposition of the marls, or varying conditions of depth, of which there is no

evidence. In any case, a land area of such limited extent could not affect the deposits over so great an area as the phenomena to be recorded were noted.

Hence, in summing up the criteria upon which we may base our judgment concerning the origin of the Santa Fé Marls of this region, we need only consider the conditions that should prevail near the central portion of such a lake. Briefly, then, if these marls are of lacustrine origin they should exhibit:

1. No great variations in texture and composition in vertical section.
2. No beds of conglomerate.
3. No marked and sudden variations in respect to the thickness and areal extent of the component beds.
4. Few unconformities of erosion.
5. No extensive cross-bedding at high angles.
6. A lacustrine rather than a land fauna or flora.

If, on the other hand, these marls are of alluvial origin, they may exhibit any or all of the above phenomena.

A detailed study of the numerous exposures of the Santa Fé Marls in the Cerrillos region developed the following facts:

1. *The Santa Fé Marls vary greatly in texture and composition in vertical section.* Lying horizontally upon the leveled edges of the upturned Cretaceous strata we most frequently find a bed of peculiar conglomerate or breccia as the basal member of the Marl group. Above it is frequently found a greater or less thickness of very fine, soft marls, with bands of fine-grained sandstones, and coarser layers of pebbles and boulders. All of these variations may be seen in the same vertical section, beds of fairly coarse gravel sometimes capping the finest marls, and in turn being capped by these same fine marls or sands; while good-sized pebbles not infrequently are noted in all the layers.

2. *These Marls contain beds of conglomerate.* As just stated, the basal member of the Marl group in this district is usually a conglomerate of subangular pebbles, cemented by a calcareous cement. In a few places the conglomerate is lacking, while in others a similar bed appears higher in the series.

3. *These Marls show marked and sudden variations in respect to the thickness and areal extent of the component beds.* The peculiar conglomerate so frequently seen as the basal member of these Marls is only 2 or 3 feet thick at the exposures east of Cerrillos; a

quarter of a mile north it is lacking entirely, fine marls resting directly on the upturned Cretaceous beds; a few hundred yards northeast of the last point it reaches a thickness of 20 feet, while a half mile west a thickness of 30 feet is attained. In other localities a variation of from 3 to 30 feet was noted. The same variation was noted in the finer marls and sands. A stratum of pinkish marl a foot thick not infrequently thins out and disappears entirely in a few hundred feet, while a sand-stone of the finest texture may grade into a fairly course pudding-stone. If detailed sections were made at every exposure in the district, probably no two such sections would correspond, except in a very general way, so great are

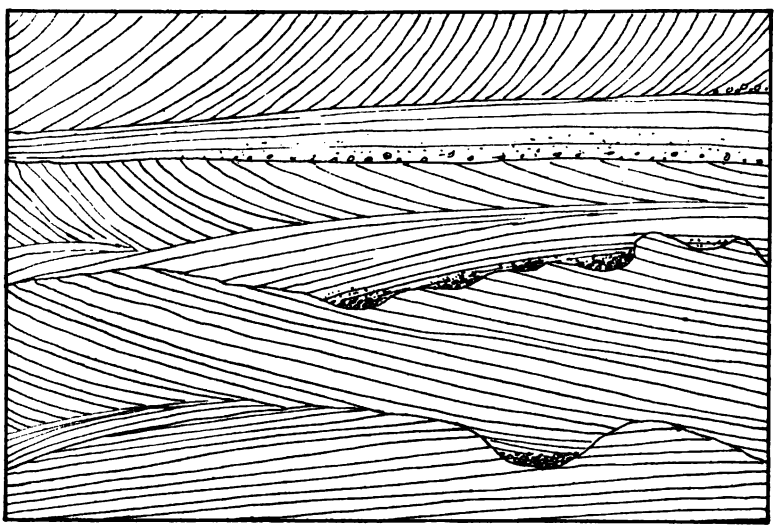


FIG. 3. Diagram Showing Cross-bedding and Unconformities in Santa Fé Marls.

the variations exhibited. Comparatively small exposures, seen from a distance, appear beautifully and perfectly stratified. When examined more carefully, or when the attempt is made to trace a given layer any great distance, the true condition is soon made apparent.

4. *The Marl beds show innumerable unconformities of erosion throughout.* When carefully examined, those exposures which appear the most evenly stratified show numerous and excellent examples of erosion unconformities. The accompanying diagram (Fig. 3) reproduces the conditions noted in a few square feet of the

face of the exposure at the eastern end of San Marcos Arroyo, shown in Fig. 2.

It will be seen that deposition was followed by erosion, then by deposition again, this process being repeated indefinitely. When erosion was progressing, large pebbles were rolled along the little channels, some of which were left to be covered by the fine marl or sand when deposition again took place. In this way pockets of large gravel are found in little hollows cut out of and covered over by the finest of sediments. The small (as well as large) scale upon which these unconformities are developed, and their great number, shows that the time element was not so important a factor as the conditions under which the beds were formed.

5. *These Marls show an extensive development of cross-bedding at high angles.* The foregoing diagram (Fig. 3) also shows the cross-bedding noticed in a small portion of the exposure in San Marcos Arroyo. This cross-bedding, from the lowest to the highest angles (up to 35 or 40 degrees), is characteristic of the deposits at numerous localities in the Cerrillos district.

6. *The fauna of these Marls, as found elsewhere, is essentially a land fauna.* In the Cerrillos district itself no fossils were found in these beds, but Cope describes a land fauna from several places in the same deposits. He himself comments on the utter absence of fish or crocodile remains, and mentions what may be the remains of roots of plants, occurring in a vertical position.

It is also to be noted that all the evidences of a lake shore-line were entirely absent.

The above facts seem conclusive. It is evident that the Santa Fé Marls cannot be of lacustrine origin, but must be the result of subaërial deposition. This conclusion is necessitated not alone by a detailed study of the beds themselves, but also by a general survey of the physiography of the region as a whole. One of the most striking features of the country is the beautiful development of the alluvial fans, the materials of which are these Marls. In every direction from each mountain range there spreads out at a low and uniform angle, a gently inclined plain, the low angle gradually decreasing the farther away from the range one goes. This plain inclines away from the range at an angle of from 5° to 6° at the mountains' base, and is seen to be composed of laterally confluent alluvial fans, each fan heading at the mouth of a mountain cañon. Some of these fans, spreading out from the largest

cañons of the larger ranges, are seen to be at least ten miles in breadth, by fifteen miles or more from cañon mouth to outer base of the fan. As a rule, however, the individualities of the various fans are soon lost, the whole merging to form a broad, sloping plain.

At the present time these alluvial fans are being dissected by numerous streams and arroyos. This dissection, however, is not well advanced, and the portions of the fans nearer the mountains remain intact, only being cut by the narrow channels of young streams. In some places, indeed, it would seem that aggrading of the fan has not yet entirely ceased, while in others, where erosion has begun to remove the fan, it is evident that the aggradation ceased quite recently, and we find Recent fossils in the upper layers. In fact, when seen from a distance, the fans seem so perfect that it is hard to realize they are not all being built up before one's eyes. The delicate adjustment of the slopes, and the uniform level of those slopes for miles in all directions from a mountain range, certainly indicate a condition but recently reached, and not greatly affected since.

AGE.

Concerning the age of the Santa Fé Marls the Cerrillos district offers little evidence. No fossils were found at this locality, and we are forced to rely on data gathered elsewhere. A résumé of the available evidence is given below.

Dr. Hayden, in speaking of these Marls, said:* "To this group I have given the name of Santa Fé marls; and they are doubtless of the age of upper Tertiary, and synchronous with the upper beds of the White River group as seen along the North and South Forks of the Platte and near Cheyenne. * * * I have as yet obtained no well-defined fossils from either the Santa Fé or Arkansas marls; yet bones of some large animal, probably mastodon or elephant, have been found in them."

According to Professor Cope,† Hon. William F. M. Arny, an early governor of New Mexico, was the first to secure vertebrate remains from these Marls. "He obtained from the regions northwest of Santa Fé, the fragments of a lower jaw of a *Mastodon productus* Cope."

The next observations of vertebrate fossils were made by the

* Prelim. Field Rep. U. S. Geol. Surv. of Col. and New Mex., 1869, p. 90.

† U. S. Geog. Surv. West of 100th Mer., Vol. IV., Pt. II., p. 24.

members of the Wheeler Survey of 1873. Francis Klett and Dr. O. Loew obtained a number of specimens from near San Ildefonso.*

In 1874 Professor Cope visited this region, and from the locality near San Ildefonso secured thirty-one species of vertebrates. In discussing "The Loup Fork Beds of the Valley of the Rio Grande," † (the Santa Fé Marls), Professor Cope describes the beds near San Ildefonso, some 25 or 30 miles north of Cerrillos, as being "alternately softer and harder calcareous sandstones and conglomerates, varying from white to greenish gray and light rufous"; and then continues: "They dip generally 10° to 15° toward the east, and away from the basaltic mass of the Jemez (Cochiti) range. They contain the remains of extinct *Vertebrata*, mostly *Mammalia*, which have enabled me to correlate them with the Loup Fork Tertiary of Colorado and Dakota. The species discovered by our party number thirty-two, of which twenty-six are Mammals, three Birds and two Reptiles." In his paper entitled "Notes on the Santa Fé Marls and Some of the Contained Vetebrate Fossils" ‡ Professor Cope speaks of the presence in these beds of "the genera *Hippotherium*, *Protohippus*, *Procamelus*, *Cosoryx*, *Merychyus*, and known Pliocene species of other genera, among which may be mentioned *Canis*, *Aceratherium*, etc." A number of new species were also established, and descriptions appended.

While on this same expedition Professor Cope visited the northern end of the Sandia Mountains, and examined the marls or clays, some 40 feet in thickness, which occupy the intervals between low hills of "Cretaceous No. 3," near the village of Placitas. He says: § "I obtained teeth and other bones of *Elephas primigenius* subspecies *columbi* from this bed, and found bones of Elephants in place in the banks of the arroyo. Shells of *Planorbis*, *Physa*, etc., indicte the lacustrine character of the deposit which I have called the Placita marls." On the basis of the above fauna Professor Cope refers these beds to the post-Pliocene epoch. As will appear below, I am convinced of their identity with a part of the Santa Fé Marls.

An extinct vulturine bird || was reported from these Marls near

* *Loc. cit.*

† *Ibid.*, pp. 20–25.

‡ *Proc. Phil. Acad. Nat. Sci.*, 1874, pp. 147–152, pls. IX–XI.

§ U. S. Geog. Surv. West of 100th Mer., Vol. VI., Pt. II., p. 25.

|| *Proc. Phil. Acad. Nat. Sci.*, 1875, p. 271.

BASALT FLOW CAPPING SANTA FÉ MARLS. (West of Cerrillos Hills.)

Santa Fé, and described as *Cathartes umbrosus* Cope. Further examination showed it to belong to the vulturine division of Falconidæ, and the name was changed to *Vultur umbrosus*.

From near Santa Cruz Professor Cope reports * the bones of *Mastodon* and *Aceratherium jemezanum* Cope, in beds referred to the Santa Fé Marls.

Professor Stevenson reports no fossils from the Cerrillos region, but says,† regarding the age of his so-called Galisteo group, which we have seen to be identical with the Santa Fé Marls: "Whether the Galisteo group belongs to the Miocene or the early Pliocene could not be determined. * * * It cannot be older than early Miocene or newer than early Pliocene." Regarding the upper part of these Marls, which part alone he calls Santa Fé Marls, Professor Stevenson merely states that "Professor Cope has determined that the Santa Fé Marls belong to the Loup River epoch of the Pliocene."

Within the last year or two Dr. W. G. Tight, of the University of New Mexico, has found the skeleton of an elk and some freshwater shells near the southern end of the Sandia Mountains, in beds which he considers identical with those in the Cerrillos district.

In summing up the evidence we cannot doubt the Loup Fork age of a part of these beds, at least. Even if we were to assume that the beds at San Ildefonso were not identical with the true Santa Fé Marls, the remains of *Mastodon productus* and *Vultur umbrosus*, from the typical locality of these Marls, would be sufficient proof of their Loup Fork age. At the same time I do not believe anyone who visits the several localities can doubt for a moment but that the Placitas marls at the north end of the Sandia Mountains, and the deposits studied by Dr. Tight at the south end of the same range, are parts of great alluvial fans closely identical with those forming the Santa Fé Marls further north and east. Nor do I believe they could doubt the recent age of a portion, at least, of these Marls as shown in the typical locality. But the Placitas marls contain a post-Pliocene fauna, while Dr. Tight finds an elk in the beds at the southern end of the Sandias.

There is only one explanation, and that a very reasonable one, that will account for the above conditions. We may well believe that these great alluvial fans were forming in the Loup Fork

* U. S. Geog. Surv. West of 100th Mer., Vol. IV., Pt. II., p. 23.

† U. S. Geog. Surv. West of 100th Mer., Vol. III., Supplement, p. 162.

epoch, and so entombed the remains of the fauna that roamed over them at that time. These fans, with possibly more or less interruption, have continued to form until recent time. In the more recent portions of these deposits were entombed the remains of post-Pliocene faunas. It is possible that these fans may have been greatly eroded at times, and subsequently built up again, due to varying geologic conditions. If such were the case, it would be well-nigh impossible to detect it in beds of this nature, where erosion unconformities and frequent alternations of beds of varying texture and composition are frequent even where deposition is practically continuous.

So while the Santa Fé Marls represent a period extending from the Loup Fork epoch to the present time, I do not believe it possible to subdivide the beds, or to recognize the different stages represented, except where fossils are immediately present.

Although these fans are now being dissected in places, and rivers and arroyos have cut out narrow valleys in them, I have seen local instances of aggradation on their surfaces. Bones of cattle and horses have become partially buried by the fine silt that may be seen washing out over the inclined plane during any heavy shower, thus giving a demonstration of the processes that were at work when the bones of the *Mastodon* were being entombed in Tertiary times.

The Galisteo Sand Group.

Laramie (?).

Along the eastern border of the Cerrillos district the Galisteo Creek and its tributary arroyos have removed the Santa Fé Marls, revealing a series of easterly dipping red sandstones which Hayden has named the Galisteo Group. The beds of this series are mainly deep brick red or purplish-red sands, sandstones and marly sand, with occasional bands of a yellow or white color. So far as known this group contains no fossils except the silicified trunks of trees. These occur in great numbers at a point a few miles east of Cerrillos, and give the locality its name, the "petrified forest." As a rule the tree trunks are found weathered out in large pieces, but a number were seen lying horizontally imbedded in the sands.

The close resemblance of these beds to those of the "Red Beds" proper, of Jura-Triassic or Permian age, has led to no little confusion, as will be apparent on reading the literature summarized

below. The marked contrast between these beds and the yellow sandstones immediately below, has led me to adopt the contact between the two as the division line between the Galisteo Group of Hayden and the series for which I propose the name Madrid Group. In thus placing the lower limit of the Galisteo Group at the base of the red sandstone series I believe I am following exactly the limit implied, though not directly stated, by Hayden. As noted near the close of this section, there is an additional argument for this location of the limit in the evidence of a marked change at this point in the physical conditions attending deposition.

A résumé of the literature bearing on the Galisteo Group, together with the conclusions of the various writers, is given below.

In July, 1846, Dr. Wislizenus visited the gold region south of the Galisteo, crossed the creek near Cerrillos, and wrote*: "Ascending afterwards to the hills, I met everywhere with a red and brown sandstone, looser or more compact, and with large masses of petrified wood."

In September of the same year Lieutenant Abert made a trip from Santa Fé to the gold mines in the Ortiz Mountains. In describing the journey, he says: † "Toward the latter part of the day we entered a very sandy country; here lay huge masses of sandstone and fragments of immense petrified trees."

In both of the above cases I have little doubt but that the "petrified forest" in the Galisteo Group is referred to.

In the fall of 1853 Jules Marcou visited the Cerrillos region, and referred the Cretaceous rocks farther east to the Jurassic and Triassic. It does not appear from his notes,‡ however, that he studied the Galisteo Group proper, as has been thought by some.

On his second visit to this region, in 1859, Professor Newberry noted that the rocks exposed in the valley of the Galisteo consisted of portions of the Triassic, Cretaceous and Tertiary, and said that the Triassic rocks contained great numbers of silicified trunks of coniferous trees.§

---

* Senate Miscellaneous Document No. 26, 30th Congress, 1st Session, p. 29.

† Senate Executive Document No. 23, 30th Congress, 1st Session, pp. 32–33.

‡ Expl. and Surv. for a R. R. route from Miss. Riv. to Pac. Ocean, Vol. III., Pt. IV., No. 2, pp. 140–141.

§ Rep. of the Expl. Exped. from Santa Fé, N. M., to the Junc. of Grand and Green Riv., 1859, Geol. Rep., pp. 38–42.

In 1867 Dr. Le Conte visited the region and in his report* mentions "probable Trias" near Galisteo Creek containing great quantities of silicified wood.

In 1869 Dr. Hayden made a trip from Santa Fé to the Ortiz Mountains, at which time he described and named the Galisteo Group. He says:† "As we descend the hill into the valley of the Galisteo Creek, we have a wonderful exhibition of the variegated sands and sandstones, which at first appear like the upper series of red beds on the east side of the mountains, but which I at once suspected were new to me in this region. * * *

"Passing up the Galisteo, eastward, we observed the variegated sands and sandstones, rising above the coal strata, and concealing them on the northeast and east flanks of the Placiére Mountain, inclining at all angles from five degrees to fifty degrees. These sandstones are of varied texture, from a fine aggregate of quartz particles to a rather coarse pudding-stone. In some of the beds there are irregular layers, of a dull, rusty brown, concretionary arenaceous limestone, in which I searched in vain for fossils. One of the most peculiar features of these beds, and one which I have never seen in any group before, is the great variety of colors, from a light reddish tint to a deep brick red, sometimes dull purplish light, and very deep yellow, white, brown, drab, etc. The only fossils I could find were enormous silicified trunks of trees. * * * I have named these beds the Galisteo sand group, as they are confined, so far as I know at present, to the valley of the Galisteo, although they pass under the Santa Fé marls, and the northern limit is concealed from view."

Dr. Hayden clearly states his idea of the age of this group, as well as its relations to the underlying and overlying rocks, in the following words: "We have, therefore, in the valley of the Rio Grande, if my investigations are correct, three groups of tertiary beds of different ages. (1) The coal strata, with abundant impressions of deciduous leaves, lying above well-marked Cretaceous beds. (2) The Galisteo sand group, which plainly overlies the coal strata, but inclines equally with and conforms to them. (3) The Santa Fé marls, which are of much later date than either of the other two, and rest unconformably upon the Galisteo group, and never incline more than five or ten degrees."

* Notes on Geol. of Surv. for the Extension of Union Pac. R. R., Phila., 1868, pp. 36–41.

† Prelim. Field Rep. U. S. Geol. Surv. of Col. and New Mex., 1869, pp. 66–68.

In 1874 Dr. Loew visited this district and in his report stated * that "between the Placer Mountains and Santa Fé we cross several valleys of erosion, in which the Triassic beds with their characteristic fossil wood are well exposed."

In the same year Professor Cope visited the region, and according to his statement, studied the Galisteo Group, both in the valley of the Galisteo and on the eastern flank of the Sandia Mountains. He says: † "The age of the Galisteo sandstone is a point not satisfactorily decided. So far as their position on the flanks of the Sandia Mountains indicates, they may belong anywhere from Cretaceous No. 3 to the Coal Measures. That they are not of Tertiary age, as has been supposed by some, is clear. Dr. Hayden's observations lead to the conclusion that they are not older than the Cretaceous, since he states that they overlie the coal of Placer Mountain, which itself is superior in position to undoubted Cretaceous beds. If these positions be correct, this group constitutes a special member of the Cretaceous formations." A careful study of Professor Cope's description of the beds, ‡ and of the position of his route through this region, has convinced me that the beds visited and described by him in the Galisteo valley were the "Red Beds" proper, of Permian of Jura-Triassic age, exposed at the base of the Galisteo monocline, several miles west of the exposures of the Galisteo Group. The fact that he did not see the coal is further proof of the error. There is no evidence to show that he ever saw the Galisteo Group itself. The beds seen by him on the flank of the Sandias are doubtless the same as those he mistook for the Galisteo Group, and lie below the Cretaceous and immediately upon Upper Carboniferous limestone. The lithologic similarity of the Red Beds proper and the red sandstones of the Galisteo Group, together with the fact that their strike and dip, and relations to the overlying Santa Fé Marls are all identical, probably led to the error.

In 1875 Professor Stevenson, in commenting on Dr. Hayden's description of these beds, said: § "A careful comparison of this section as given by Dr. Hayden, with the details of the geology along Dr. Newberry's route from Santa Fé westward, as given in

* Rep. of Chief of Engineers, 1875, Pt. II., p. 1028.

† *Ibid.*, p. 997.

‡ *Ibid.*, p. 996.

§ *Proc. Am. Phil. Soc.*, Vol. 14, 1875, p. 462.

Ives' report, will, I think, satisfy everybody that Dr. Hayden has by some oversight inverted the order, and that the Galisteo group *underlies* the coal group. The Galisteo group is unquestionably the Triassic, as abundantly appears from the descriptions of that system in New Mexico, by Newberry and Le Conte."

Later in the same year Professor Cope quoted the above criticism of Stevenson's and replied * to it by saying that his own study of the region convinced him that the Galisteo Group rested upon the coal group, as stated by Dr. Hayden. The resemblance of this group to the Triassic he regarded as accidental. As we have just seen, however, Professor Cope did not have the true Galisteo Group in mind.

In 1878 Professor Stevenson visited the region, and gave an extensive account of the geology in his report † to Lieut. G M. Wheeler. In this report he considers the Galisteo Group of Hayden ‡ to be a part of the Laramie or coal formation, and recognizes its true position above the coal.§

In 1898 Dr. Herrick published a brief account of the geology of the Cerrillos district || in which he referred to Cretaceous sandstones east of the town of Cerrillos containing abundant silicified trunks of trees. That he later considered these beds of Jura-Triassic age appears in a paper on the "Geological Associations in New Mexico Mining Camps,"¶ in which he attributes the origin of the turquoise to metamorphism of these red sandstones by the intruded lava. In a note to the writer, he refers other inclusions of red sandstones, seen further east, to the Jura-Triassic. All inclusions of red sandstone in that locality belong to the Galisteo Group.

When I began my study of this series I was impressed with the close lithologic resemblance of these beds to those of the Red Beds proper, and noting several faults parallel to the strike in these beds themselves, was led to adopt the idea of such a fault between the

* *Proc. Phila. Acad. Sci.*, 1875, p. 360.

† U. S. Geog. Surv. West of 100th Mer., Vol. III., Supplement, 1881.

‡ In this connection it must be borne in mind that the extensive description of "The Galisteo Group" given in Professor Stevenson's report does not apply to the true Galisteo Group of Hayden, but to the Santa Fé Marls of that author. Professor Stevenson considered the true Galisteo Group under the head of his "Laramie."

§ *Ibid.*, pp. 159, 160, etc.

|| *Bull. Univ. New Mexico*, Vol. I., pp. 109–114.

¶ Rep. of the Governor of N. Mex. to the Secretary of the Interior, for 1900, pp. 257–260.

red sandstones and the light yellow series just west as a working hypothesis, thus regarding this red series as a faulted-up portion of the Jura-Trias or Permian. A very careful study of several good exposures of the contact of these two series failed to reveal any evidence of a fault. The occurrence, in the valley east of Cerrillos, of the red sandstones standing vertical, and at the same time parallel to the yellow sandstones of the coal or Madrid Group, showed that the theory of a fault must be abandoned.

Thinking the fossil tree trunks might throw some light on the question, I submitted thin sections to Mr. Frank H. Knowlton. He found that they indicated a tree unknown in the Red Beds

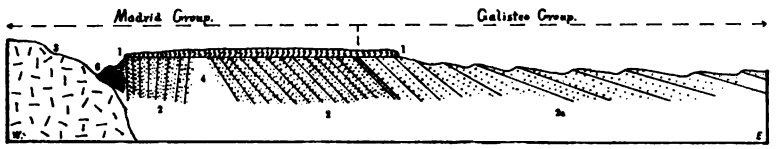


FIG. 4. Section east of Cerrillos; 1, Santa Fé Marls; 2, sandstones; *2a*, red sands of Galisteo Group; 3, intrusive andesite (laccolith); 4, concealed; 6, carbonaceous shales.

proper, but of evident Upper Cretaceous or later affinities. In a letter to me on the subject, he said: "The wood is a dicotyledon, and while it has been somewhat distorted by fossilization, it appears to be a species of *Quercus*. In any event it shows a highly organized dicotyledonous tree, wholly unlike anything known from the Jura-Trias, and might well belong to the Upper Cretaceous or later."

Both stratigraphic and palæontologic evidence thus proving the more recent age of these beds, it is possible to arrive at a fairly accurate idea concerning their relations. The coal seams at Madrid are but a few feet above undoubted Upper Fort Pierre beds. As we shall see, both the stratigraphic position and the fossil leaves indicate the Fox Hills age of the coal. Conformable upon the coal are over a thousand feet of massive yellow sands, whose upper member is a 25-foot band of very white sandstone. As will be seen elsewhere, I include this series with the coal beds, and give the name Madrid Group to the whole, considering this group to be of Fox Hills age.

Immediately above the white sandstone band at the top of the Madrid group, the deep red sands of the Galisteo Group are found. The contrast with the underlying Madrid Group is very marked.

Evidently a marked change in the physical conditions attended the inauguration of this new series. It may be that this change was in some way connected with the coming in of the Laramie epoch, and that the Galisteo Group is of Laramie age.

The upper limit of these beds was not seen, but it may well be doubted if anything higher than Laramie is represented. Previous to the accumulation of the Loup Fork deposits of the Santa Fé Marls there was a vast period during which the region was elevated and worn down to a peneplain, reëlevated, and again subjected to erosion. It is not unreasonable to suppose that this erosion period dated back to or near the close of Laramie time, the great upheaval which tilted and elevated these beds being the same which inaugurated Tertiary conditions. This uplift resulted in much faulting of the beds, so that it was impossible to arrive at any satisfactory opinion regarding their thickness. Along several of these great strike faults the beds on the down-faulted side are turned up until they stand vertical, giving beautiful illustrations of this common result of such displacements. There are at least between 1,500 and 2,000 feet of these deposits, while the thickness may possibly be greater.

That we have typical "Red Beds" of late Cretaceous or Laramie age is clearly shown, and the danger of placing too much dependence upon lithologic similarity again illustrated. That this point needs to be emphasized especially in connection with the "Red Beds" of the West is soon apparent on reading the geological literature of regions where these beds are well developed. The tendency to regard all the Red Beds as belonging to the Jura Triassic or Permian is marked. It was on this basis that Professor Stevenson regarded the Galisteo group as "unquestionably Triassic." In a paper above referred to Dr. C. L. Herrick says: "The Jura-Triassic sandstones are widely distributed and are easily recognized by the red color." This same idea has been shared by others, and in my own case led to a wholly wrong assumption as a working hypothesis.

The Madrid Coal Group.

Fox Hills.

The arroyos tributary to the Galisteo on the south side of that creek have removed the Santa Fé Marls from a considerable area south of the town of Cerrillos, revealing a series of easterly dip-

ping yellow and white sandstones, over a thousand feet in thickness. The lower 300 feet of this series contain several coal seams of workable thickness, together with some shale beds. The upper portion of the series consists almost wholly of massive yellow and white sands. To this series I propose to give the name "Madrid Group." The coal seams outcrop at the town of Madrid, and the region is known as the Madrid coal field.

It is difficult to arrive at an accurate estimate of the thickness of these beds. In the Madrid field several extensive and numerous smaller interstra sheets of the intrusive occur. The Madrid section (Fig. 5) shows between 200 and 300 feet of the lower portion of this Madrid Group, together with several of these intrusive sheets. The upper portion of this group is best exposed on the north side of the creek, a mile or two east of Cerrillos (Fig. 4). Here the yellow and white sandstones are upturned by the Cerrillos intrusion and the Santa Fé Marls deposited upon their planed off edges (see plate G). There are several faults shown in the section, but in one place 850 feet of the massive sands were traced without a break. A study of the section will make it apparent that even when due allowance is made for the faults, a much greater thickness of sediments is represented. It is probable that the whole of the Madrid Group, as indicated by the Madrid section and the section east of Cerrillos, comprises anywhere from 1,500 to 2,000 feet of strata. The relations in the field indicated that

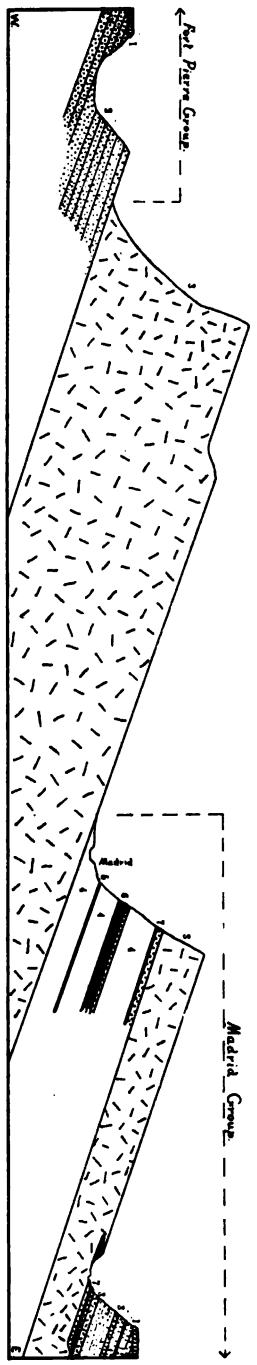


FIG. 5. Madrid Section: 1, Santa Fé Marls; 2, sandstones; 3, intrusive andesite; 4, concealed; 5, bituminous coal; 6, lignitic shales; 7, anthracite.

the lowest bed in the section east of Cerrillos, of carbonaceous shales, belonged somewhere near the upper part of the Madrid section. It is not probable that any notable thickness of beds has been omitted, nor that any duplication has occurred, in thus correlating the two sections.

The coal in the lower portion of the Madrid Group has proven of great interest to geologists, and so many references have been made to it in the literature that it would be almost impossible to secure them all. It is of interest, however, to note the observations of the earlier explorers and the conclusions arrived at by several geologists regarding the age and origin of the anthracite bed — the upper workable seam in the region.

In 1846 Lieut. Abert stated* that he found evidence of coal on one of the tributaries of Galisteo Creek.

In 1857 Professor Blake visited the Cerrillos region and published "Observations on the Geology of the Rocky Mountain Chain in the Vicinity of Santa Fé, New Mexico."† He mentioned the anthracite coal of the Madrid field, and provisionally referred the beds to the Carboniferous. Similar notes were published elsewhere.‡

During his first visit to this general region in 1858, Professor Newberry secured samples of the anthracite coal from Mr. Mercure in Santa Fé, but was unable to visit the locality from which they came.§ In 1859, however, Professor Newberry again visited the region, and studied the coal beds of the Madrid Group. He recorded‖ the occurrence of lignite in Cretaceous on both sides of the Galisteo Creek, and noted that on the south side of the creek an "outburst and overflow of trap" had changed the lignite into good anthracite coal.

In 1867 Dr. Le Conte studied the geology of this region.¶ He speaks of the anthracite bed in the Madrid Group as "a coal bed, which by the overflow of a lava stream, now congealed into gray

* Senate Executive Document, No. 25, p. 37.

† *Proc. A. A. A. S.*, 1859, pp. 314–319.

‡ *Proc. Boston Soc. Nat. Hist.*, 1859, pp. 64–70.

§ Rep. upon Colo. Riv. of the West, J. C. Rives, Wash., 1861; Pt. III., pp. 98–99.

‖ Rep. Expl. Exped. from Santa Fe, N. M., to Junc. of Green and Grand Riv., 1859; Geol. Rep., pp. 38–42.

¶ Notes on Geol. of Surv. for Extension of Union Pac. R. R., Phila., 1868, pp. 36–41.

prophyry, has been converted into a substance resembling anthracite, but much lighter and more brittle than the anthracites of the older formations." Dr. Le Conte then gives a detailed section of a portion of these beds, and refers them to the lower Cretaceous in the following words: "From the proximity of the marl series, the absence of all characteristic upper and middle Cretaceous shells, and the known existence of lower Cretaceous lignites west of the Rio Grande, I infer that the anthracite beds belong to that period."

In 1869 Dr. Hayden studied these beds, and wrote about them as follows:* "The outcroppings of coal on the northwest side of the Placiére Mountains are of great interest. They were first exposed in the center of the little branches that run into the Galisteo. The first one is about five miles south of the Galisteo. The coal is in the natural condition.

"* * * At another locality there is a bed of coal, which has been changed by an enormous dike into anthracite. (Then follows section of beds.) The dip of all the beds is fourteen degrees east. They are overlaid by a thick bed of columnar basalt. The dike that covers the coal bed trends about north and south, or a little east of south." Dr. Hayden mentions the occurrence of abundant impressions of deciduous leaves with the first coal bed mentioned, and refers the whole of the coal group to the Tertiary.

In 1874 Professor Cope visited the region, and according to Professor Stevenson † placed these coals in Cretaceous No. 3. As stated elsewhere (p. 335), I am not able to find that Professor Cope ever visited this immediate locality, and his references to the position of the coal were made upon a mistaken idea of the identity of the Galisteo Group.

In the same year Dr. Loew visited the region, mentioned ‡ the occurrence of the seams of coal in the arroyo south of Cerrillos, and gave several analyses § of the anthracite. Dr. Loew says: ‖ "The coal is probably of Carboniferous age."

In 1878 Professor Stevenson made a study of the geology of this locality, and in his report described ¶ the coal series at some

* Prelim. Field Rep. U. S. Geol. Surv. of Col. and New Mex., pp. 67, 68.

† U. S. Geog. Surv. West of 100th Mer., Vol. III., Supplement, p. 35.

‡ Rep. of Chief of Engineers, 1875, Part II., p. 1028.

§ U. S. Geog. Surv. West of 100th Mer., Vol. III., pp. 632, 634.

‖ *Ibid.*, p. 633.

¶ U. S. Geog. Surv. West of 100th Mer., Vol. III., Supplement, pp. 126–130.

length, giving detailed sections. Professor Stevenson refers this group to the Laramie.

In 1895 Professor Stevenson again visited the Cerrillos region, and made a more detailed study of the Madrid Group. His conclusions * deal more especially with the nature, occurrence and origin of the anthracite, and are considered elsewhere in this report. The geological relations are described in some detail, however, the beds being referred, as before, to the Laramie. Regarding the Fox Hills Professor Stevenson says: † "The Fox Hills stage of the Rocky Mountains region is not represented in this area."

In 1898 Dr. Herrick studied the Ortiz and Cerrillos region, and in his published notes ‡ briefly describes the coal series and refers it to the Cretaceous, no more definite a reference being made.

In the summer of 1899 and 1900 I made several short excursions into this region and on stratigraphic grounds was led to refer this Madrid Group to the Fox Hills. The more detailed work of the summer of 1902 has served to confirm the former reference.

her west, in the valley of the Rio Puerco, are exposed a series of lignite beds, above which are massive yellow standstones similar to those of the Cerrillos region. In these yellow sandstones I found abundant fragments of sharks' teeth and a few marine shells. On the basis of shells and leaves which he collected here, Dr. C. L. Herrick referred these beds to the Fox Hills.

In the Madrid region about 100 feet below the lowest coal bed are abundant marine fossils of Upper Fort Pierre age.§ From 1,500 to 2,000 feet above the coal of the Madrid Group, in the Galisteo Group which overlies it conformably, are silicified tree trunks of Upper Cretaceous or later affinities. In the Madrid Group itself are found fossil leaves, one species of which is only known from the Fox Hills, while another is only known from beds of doubtful, but probable Fox Hills, age. In view of these facts, and since lignites in other parts of the Territory are known to be of Fox Hills age, I have no hesitation in referring the Madrid Group to that period.

The details of the Madrid Group are shown in the following sec-

* *Trans. N. Y. Acad Sci.*, Jan., 1896, pp. 105–122.

† *Ibid.*, p. 111.

‡ *Bull. Univ. New Mex.*, Vol. I., pp. 109–114.

§ See Part II., Palaeontology, of this report.

SANDSTONES OF MADRID GROUP, CAPPED BY HORIZONTAL SANTA FÉ MARLS. (East of Cerrillos.)

tion, compiled from the lower part of the section east of Cerrillos (Fig. 4) and the upper part of the Madrid section (Fig. 5). Minor coal seams occur in some of the shale beds, but were not visible in the sections. The beds are given in descending order:

	Feet.
Massive white sandstone	25
Marly sands	Few
Massive yellow sands with occasional loose, marly bands	850
Concealed (loose marly sands? with possible fault)	175
Massive and loose shaly sands	350
Loose yellow sands	150
Fault.	
Loose yellow sands	100
White sandstone	15
Carbonaceous shales	50

Continued in the upper part of the Madrid section as follows:

	Feet.
Loose sand (upper part concealed)	Several
Intruded lava sheet	1
Soft sandstone	8
Intruded lava sheet	3
Soft sandstone	10
More indurated sandstone (fossil leaves)	9
Carbonaceous shales	10
Sandstones	6
Intruded lava sheet	8–10
Shales	3–4
Coal seam	2
Shales	3
Concealed	Few
Intruded lava sheet (west to Madrid)	65
Concealed (probably lava sheet)	65
Sandstone	1
Shales and coal (anthracite)	3
Sandstone	7
Shales	2
Coal (anthracite)	3
Shales	2
Concealed	100
Sandstone	16
Lignitic shales	30
Concealed	70
Coal (bituminous)	3
Concealed (sandstone and carbonaceous shales in well boring	100+
Intruded lava sheet	Several hundred

As will be seen from the above, 30 feet of carbonaceous shales with several thick bands of brown lignite are exposed in the Madrid escarpment near the mines, occurring 125 feet below the anthracite, and 70 feet above the bituminous coal. In a section a little over 200 feet in vertical extent we thus have all of the three important stages in the production of anthracite represented. The significance of this in connection with the origin of the anthracite is emphasized elsewhere. The fossil leaves, belonging to the species *Ficus uncata* Lesquereux, *Ficus rhamnoides* Knowlton, and *Aralia?* sp., were found in the 9-foot band of sandstone above the coal exposed half a mile east of Madrid, and are described and figured in Part II., Palæontology, of this report. The petrographic description of the interstrata sheets of lava occurs in Part III., Petrography. That these lava sheets were intruded between the beds is shown by the metamorphic effects both above and below the lava, by the fact that the sheets send off tongues of lava into the overlying beds, and by the deep-seated character of the intruded material. In the Madrid area these interstrata flows doubtless connected with, and had their origin in, the great Ortiz laccolith to the south.

The Fort Pierre Group.

Since the Fort Pierre shales and sandstones are found mainly along the western side of the Cerrillos district, away from the usual line of travel to the coal and placer mines, and contain nothing of special economic interest, they do not play as important a part in the literature of this region as do the groups previously discussed. It is true that in the reports of several of the earlier geologists references are made to fossils collected and other data secured from Cretaceous beds in this region, some of which references may apply to the beds of this group. But in all cases the statements are very general, or there is considerable doubt as to the beds actually under consideration.

In 1869 Dr. Hayden noted* "the dark shales of No. 4, apparently." In 1878 Professor Stevenson made a study of the region, and gave more exact descriptions of this formation.† He recorded the presence of Fort Pierre shales on the south and west sides of the Cerrillos Hills, where they were said to contain fragments of

* Prelim. Field Rep. U. S. Geol. Surv. of Colorado and New Mexico, 1869, p. 67.

† U. S. Geog. Surv. West of 100th Mer., Vol. III., Supplement, pp. 99–101, 329, etc.

huge *Inocerami* and other fossils, and beds of iron ore. The great distortion of the beds is referred to.

The Fort Pierre Group in the Cerrillos region consists of beds of dark arenaceous shales, shaly and massive sandstones, and loose sands. These beds are quite fossiliferous in places, and their fauna is described in Part II., Palæontology, of this report. So far as the greatly disturbed and faulted condition of the beds would permit one to determine, the upper part of the group consists largely of the sandstones and shaly sands, while the lower, and probably greater, portion consists of dark arenaceous shales. In

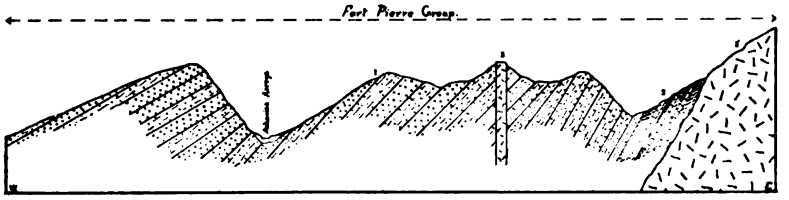


FIG. 6. Achavica Arroyo Section.— 1, Sandstones. 2, Sands and shales. 3, Intrusive andesite (laccolith and dyke).

the Achavica Arroyo section (Fig. 6) 170 feet of these sands were measured, while 160 feet appear in the Madrid section (Fig. 5). It was impossible to get any idea of the thickness of the shales below. The whole area of the low broad vale west of the Cerrillos Hills and north of the Galisteo Creek, except a narrow band along its western edge, is largely composed of these dark gray or drab shale beds. But the area is cut by a large series of intersecting dikes, faults are numerous and of unknown extent, and the beds are up-tilted, overthrown, and twisted in every conceivable manner. In one place several hundred feet of these shales appear dipping westward away from the Cerrillos uplift, but minor faults were certainly present, and more extensive ones may have been. There is little doubt but that a considerable thickness is represented, however, the whole of the Fort Pierre Group probably reaching the thickness of over 1,000 feet given by Stevenson for this group in other localities.

The detailed character of the upper sandy portion of the Fort Pierre Group may better be appreciated by a study of the typical sections, which are here repeated. The Madrid section (Fig. 5) was made along a nearly east and west line passing through the town of Madrid, and was about a mile and a half in length. This section shows an easterly dipping series of sandstones and shales,

with several intrusive sheets of lava. At the base of this section, about a mile west of Madrid, are found beds of yellow and white sands, overlain by one of the intrusive sheets, as follows:

Intruded sheet of lava.	Feet.
Massive sandstone	30
Shaly "	6
Massive "	6
Shaly "	40
Shaly sandstone with concretions	30
(Small hiatus.)	
Loose sands with concretions	50

The lower eighty feet of this section were fossiliferous, the fossils gathered being mostly weathered out, probably from the concretions, and were of Fort Pierre age.

The Achavica Arroyo section (Fig. 6) was made one mile northwest of Grand Central Mountain, in Achavica Arroyo, where are exposed a series of sandstones and shales, dipping sharply away from the intrusive core of the main uplift, with which these beds are in contact at the eastern end of the section. At the western end the section is terminated by a fault, beyond which the beds dip toward the east, apparently away from a smaller intrusion of the lava a few rods farther west. The whole formation is considerably metamorphosed, and the strike and dip vary greatly, the average being about N. 40 E. for the former and 50 W. for the latter. The following beds are exposed, given in descending order:

[Fault cutting off section at western end (top)].

	Feet.
A. Sandstones and shaly sands	60
B. Sandstones and shaly sands	40
Small dike.	
C. Shaly sands D. Shaly sands	40
E. Sandstones and shaly sands	30
F. Mostly shales	20
Intrusive core of main uplift.	

A few fossils were found in each of the above divisions, and showed the Fort Pierre age of the beds.

In both of the above sections several new species of fossils were secured, and are described, together with the rest of the forms, in Part II. of this report. In each case enough well-known forms were present to leave no doubt as to the age of the deposits.

Good Fort Pierre fossils were also found in the lower dark shales in several places, but no satisfactory sections could be obtained.

Layers of nodular iron ore have been mentioned from these beds by several writers, some of whom attached considerable importance to the occurrence. No beds of value have been developed, nor did I see any indications of notable quantities of iron in the region.

The Niobrara Group.

Dr. Hayden speaks* of finding "the full series of the Cretaceous beds" in this locality. His more definite description is as follows:† "A great thickness of Cretaceous shales No. 2, passing up into laminated arenaceous shales, with fossils, then the dark shales of No. 4, apparently." No specific mention of Cretaceous No. 3, or the Niobrara Group, is made.

Professor Stevenson says:‡ "The limestones only of this group were seen on Galisteo Creek, where the exposures are far from being complete." He doubtless referred to the region about Galisteo, some sixteen miles further east, as he elsewhere § mentions the occurrence of small exposures of this group at that locality.

In the Cerrillos region itself I found no beds of undoubted Niobrara age, nor any limestones resembling those of this group. Just north of the town of Cerrillos is a small and imperfect exposure of Fort Benton shales, but it did not appear that anything belonging to the Niobrara was represented there. At the top of the Galisteo Monocline were found beds containing *Ostrea lugubris* Conrad, and which may belong to the Niobrara, although lithologically they more closely resemble the Fort Benton. It is also possible that some of the beds below the known Fort Pierre on the south side of the creek may belong to the Niobrara.

The Fort Benton Group.

Dr. Hayden speaks‖ of "a great thickness of Cretaceous shales No. 2" west of the Cerrillos Hills. It seems probable that the most of this "great thickness" of shales belongs to the Fort Pierre,

* Prelim. Field Rep. U. S. Geol. Surv. of Col. and New Mex., 1869, p. 66.
† *Ibid.*, p. 67.
‡ U. S. Geog. Surv. West of 100th Mer., Vol. III., Supplement, p. 98.
§ *Ibid.*, p. 340.
‖ Prelim. Field Rep. U. S. Geol. Surv. of Col. and New Mex., 1869, p. 67.

although the Fort Benton is represented. Professor Stevenson does not mention this group as occurring in the Cerrillos district, although he records* it from fifteen or twenty miles farther east.

The exposures of the Fort Benton group in the Cerrillos district are few, small and imperfect, but one such exposure gives undoubted faunal proof of its age. Just north of the town of Cerrillos, almost in contact with the intrusive mass of the main Cerrillos uplift is exposed a small bed of dark calcareous shales, striking N. 45 W. and dipping 25 N., or in toward the intrusive. This represents one of the groups of strata which are found in close proximity to the laccolith, dipping in toward it, the beds generally dipping away from the uplift in all directions. From these shales a characteristic Fort Benton fauna was collected, as noted in Part II. of this report. The shales are not well shown, but apparently are of but limited areal extent.

Several miles west of Cerrillos, just south of the main wagon road west, are exposed easterly dipping shales which form the most eastern exposure of the Galisteo Monocline. About one hundred feet of these shales are shown between interstrata sheets of lava, and from them a number of specimens of *Ostrea lugubris* Conrad, a fossil characteristic of the Colorado formation, were collected. These shales may possibly belong to the Niobrara, although lithologically they more closely resemble the Fort Benton.

Judging from the small and imperfect exposures of this group one might be led to suspect that it did not attain a very great thickness in this region. Professor Stevenson reports† that in other localities the exposures of this group are seldom good, and assigns a thickness of rarely more than 150 feet to it.

The Dakota Group.

Professor Stevenson does not report the Dakota formation from the Cerrillos region, although he mentions it as occurring in the vicinity of Galisteo a number of miles farther east. If present in the Cerrillos district at all, it is only exposed as a narrow band in the Galisteo Monocline, at the western border of the district. Dr. C. L. Herrick gives‡ the following section of the monocline at a point a little north of the creek — beds given in descending order:

* U. S. Geog. Surv. West of 100th Mer., Vol. III., Supplement, p. 97.

† *Ibid.*, p. 96.

‡ *Bull. Univ. New Mex.*, Vol. I., p. 109.

	Feet.
Sandstone with conglomerate	25
Sands and shales	30
White sandstone	3+
White sandy shales	20
White sandstone	3
Chocolate shales with concretions	75
White sandstone	175
Massive red sandstone	75*
Red shales and sands	50

The red beds at the base are doubtless the typical "Red Beds" of probable Jura-Triassic age. East of this section, and above the uppermost beds here given, are the dark gray shales with typical fossils of Colorado age. It seems not improbable, then, that the upper part of the above section, with possibly still higher beds, belongs to the Dakota Group, although definite proof is lacking.

FIG. 7. Jura-Triassic (?) Red Beds, base of Galisteo Monocline.

JURA-TRIAS (?).

The lowest beds exposed in the Cerrillos region are found at the base of the Galisteo Monocline (see foregoing section), where

* Thickness not given in Dr. Herrick's section, but supplied by writer.

are exposed 125 feet of red sandstones and shales below fossiliferous Cretaceous beds. These doubtless belong to the typical "Red Beds," and were correctly correlated by Cope with the Red Beds exposed above the Upper Carboniferous on the eastern flank of the Sandia Mountains. These beds doubtless represent what we have of the Permian and Jura-Triassic in the region, and it would not seem unwarrantable to correlate this lower part of the Galisteo Monocline section with the Jura-Trias, since the upper part only of the "Red Beds" are here represented. I am not able to present any faunal evidence in support of the correlation.

To be Continued.

ON THE USE OF INFLUENCE LINES IN GRAPHIC STATICS.*

By MYRON S. FALK.

Art. 8. Influence Lines Between Adjacent Panel Points.

Beams and girders as a rule carry the loads imposed upon them at any point in their spans; in the usual types of trusses, however, and sometimes even in the case of long girders, the load

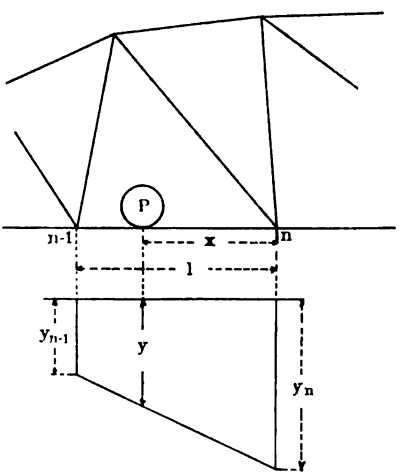


Fig. 5.

is brought upon the structure at fixed panel points only. Due to this redistribution of the load at panel points, it becomes neces-

* Continued from page 119, Vol. XXIV., No. 2.

sary to investigate the change occurring in influence lines which may have been drawn under the assumption that a load actually acts where it appears to be placed. Let Fig. 5 represent two adjacent panel points, designated as points $n-1$ and n, and let the load P be distant x from n. The effect of the load P on the members of the truss will be that due to its distribution at the adjacent panel points; in this case the equivalent effect being that due to forces equal in amount but opposite in direction to the reactions of a load P on a span of panel length l; if these forces are represented by R_{n-1} and R, there will be found:

$$R_{n-1}=\frac{P}{l} \tag{1}$$

$$R=\frac{P(l-x)}{l} \tag{2}$$

Let the ordinates of the influence line beneath the panel joints and beneath the load be designated respectively by y_{n-1}, y_n and y. Since the product of the load P by its influence ordinate must be equal to the sum of the products of its parts, each multiplied by its corresponding coördinate, there will be obtained:

$$Py = R_{n-1}\,y_{n-1} + R_n\,y_n. \tag{3}$$

By the substitution of the values of eq. (1) and eq. (2) in eq. (3) there will be found:

$$y=\frac{x}{l}y_{n-1}+\frac{l-x}{l}y_n. \tag{4}$$

In this expression x is the variable quantity and since it appears only in the first degree, the line which eq. (4) represents must be a straight line. The following rule may therefore be deduced: Any influence line due to a *single* moving load, showing the variation in any function of any part of a truss, is a straight line between adjacent panel points.

Art. 9. Determination of Stresses in Three Non-Concurrent Members of a Truss.

A problem that frequently arises in graphic construction is the determination of the stresses in three membsrs of a truss, not meeting in a point. It is assumed that the external forces are

fully known in regard to magnitude, direction and point of application; in the treatment that follows, these external forces may therefore be replaced by their completely known resultant. Let the section *mn*, Fig. 6, cut the three members *U*, *L* and *D*, of the

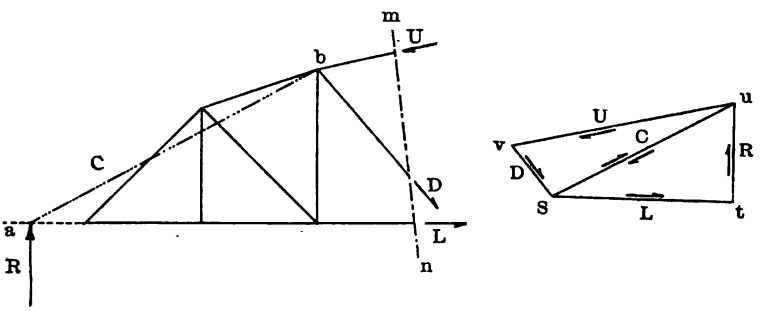


FIG. 6.

truss, and let *R* represent the position, direction and magnitude of the resultant of the external forces situated at the left of the section and which holds in equilibrium therefore the stresses in the members in question.

Continue *L* till it intersects *R* at *a*; connect *b* which is the intersection of *U* and *D*, and *a* by the line *C*, and which may, for the present, be assumed the line of action of a supplementary force acting through *a* and *b*. The force polygon *stu* may then be drawn by using the three concurrent forces *R*, *C* and *L* since only the amounts of *C* and *L* are unknown; this operation can be repeated with the forces *C*, *U* and *D*, assuming in this instance *C* to be completely known. The resulting triangle is *suv*.

If *C* in the second case be given a direction opposite to that in the first case, it is found that the supplementary force *C* is annulled; in other words, the resultant of two of the forces balances the resultant of the other two. Thus the forces *R*, *L*, *D* and *U* form a closed polygon, and the forces which are represented by the sides of this polygon are in equilibrium; the stresses *D*, *L* and *U* are then completely determined.

ART. 10. STRESSES IN THE WEB MEMBERS OF ANY SIMPLY SUPPORTED TRUSS.

In order to determine the variation in the stress in the web member or diagonal *D* of any truss such as shown in Fig. 7 in

which the moving load traverses the lower chord, let a load P move over the truss from the right abutment to panel point 3. By the method of sections and movements it can be seen that the stress in D in this case is influenced simply by the reaction R at the left abutment; it is clear therefore that with the load P between panel points 3 and 5, the stress in D will always be of the same sign. In the same way for a load P between the left abutment

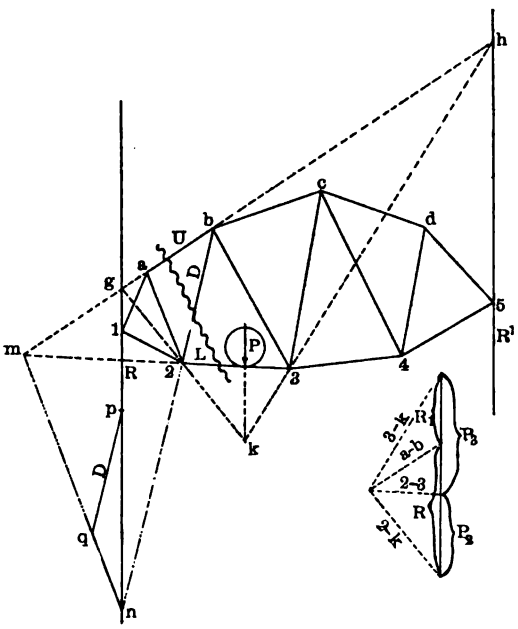


FIG. 7.

FIG. 8.

and panel point 2, the stress in D is influenced only by the reaction R'; this stress will always be of an opposite kind to that with the load between the points 3 and 5. It should however be noted that these statements do not apply to trusses of that kind in which the two chord members which are cut by the section intersect within the limits of the truss; in the treatment that follows trusses of this character are therefore excluded. It must be evident, therefore, that some point in the panel 2–3 must be a critical point for deciding how far a load may advance into the panel before the stress in the diagonal of that panel is reversed. This critical point will be found at that point where the load if applied will cause no stress at all in the member; the following construction will determine its location.

Continue the unloaded chord member $a-b$ until it meets the lines of action of the reactions at g and h; draw the lines gk and hk through the panel points 2 and 3 to the intersection k. A vertical line through k will then determine the desired critical point, according to the following proof. Assume any load P placed vertically over k. Its effect on the stresses in the members of the truss is the same as if it were replaced by its components acting at panel points 2 and 3, and the amounts of which, P_2 and P_3, are found by means of the triangle $2k3$ which is a funicular polygon for this loading on a span equal to the panel length. The force polygon corresponding to this funicular polygon is shown in Fig. 8, and represents P_2 and P_3 to scale. In a similar manner $g23h$ is a funicular polygon for the forces R, R', P_2 and P_3 and the values of the reactions R and R' of the main truss are found on the same force polygon, Fig. 8, by drawing a line through the pole O of the force polygon parallel to ab. The forces whose moment is to be taken, and which cause stress in D are therefore R and P_2; their resultant, whatever be its value, acts at the intersection of the strings ab and 23 of the funicular polygon. But this point of intersection is also the intersection of the two chord members V and L, and is the center of moments for finding the stress in D; therefore the resulting moment of R and P_2 is zero and the diagonal sustains no stress for this position of the loading. Therefore loads advancing from R' to the critical point K will cause stress of one kind, and loads from R to K stress of the opposite kind. Trusses with the loading on the upper chord are treated in precisely a similar manner, the construction to be followed in any case being simply this: Continue the unloaded chord member cut by the section, till it intersects the lines of action of the reactions; draw lines from these points through the ends of the loaded chord member which is cut by the section, and the intersection of these lines will give the desired point.

If the moving load is a uniform load, the position of the load causing the maximum stresses of opposite kinds is immediately found; the loading extends alternately from either reaction to the critical section. The value of the stress itself may be found quickly in a manner, which although approximate, is sufficiently exact to cover the usual cases occurring in practice; the stresses so found will have a value slightly greater than those which actually exist. The approximation consists simply in neglecting

that portion of the loading acting downwards at panel point 2, and assumes that the stress in the diagonal is caused only by the reaction R. The value of R may be found very simply either analytically or graphically. By means of the construction explained in Art. 9, the stress in the member may then be found as follows:

The reaction R acting at 1 holds in equilibrium the three unknown forces U, D and L; continuing U and L to intersect at m, and letting D intersect R at n, the force acting along the line mn is found to balance these two pairs of concurrent forces. In order to obtain the value of D, lay off upwards from n the value of R equal to np; at p draw a line parallel to D to intersect mn at q; pq will then be the stress in D, and will be completely determined in regard to amount and direction. In order to find the greatest counter stress, the load must cover that portion of the truss not loaded before; otherwise the operation is precisely similar to that just described.

Art. 11. Influence Line for Stress in any Web Member of a Simply Supported Truss.*

As a unit load passes over the bridge from right to left, an influence line for the stress in any diagonal such as AC of the truss shown in Fig. 9, may easily be drawn; in this case the load is carried at the panel points of the lower chord, but the methods to be used are also applicable to trusses in which the load is carried by the upper chord. It is clear that if the load is between panel points R' and B, the stress in the diagonal is always of the same sign and its magnitude varies directly as the left-hand reaction. The variation of this reaction can be indicated by an influence line for reactions, and is a straight line for a unit load. Therefore the influence line for stress in the diagonal AC may be drawn upon the reference line MN, as a straight line NL between R' and B; its slope, as yet undetermined, must be fixed by locating two of its points.

Similar reasoning holds for the distance RC; the influence line for this portion of the truss is therefore also a straight line, but since the stress is of an opposite kind from that when the load is between R' and B, the line MK is drawn below the reference line.

*That type of truss, however, in which the chord members intersect within the limits of the span, is again excluded (see page 353, Art. 10).

There still remains to be determined the influence line when the load is in the panel itself.

It has already been shown (Art. 10) that there is a point D in the panel, where a load, if placed, produces no stress in the diagonal of that panel; and it has been shown (Art. 8) that all reference lines are straight lines between panel points. Therefore the influence line in the panel itself, and to some as yet undetermined scale for load, is found by drawing any straight line through D',

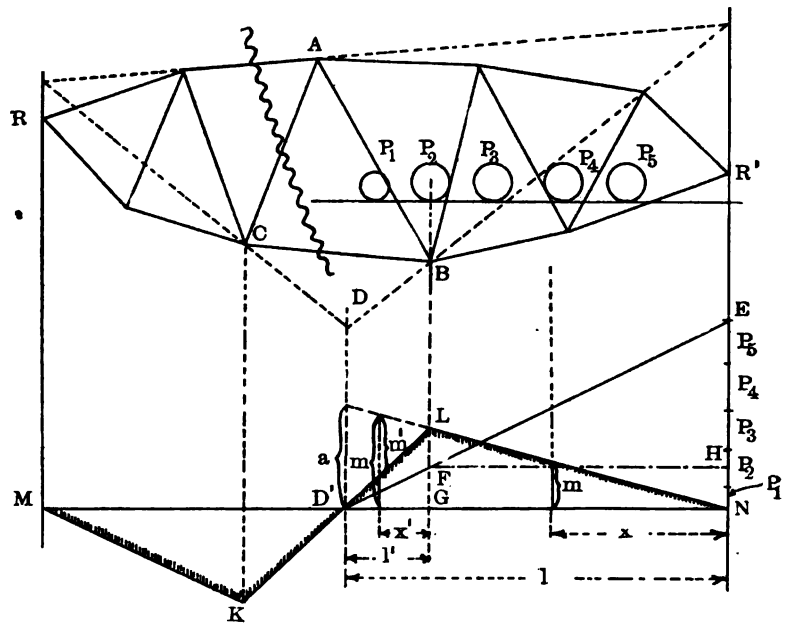


FIG. 9.

the intersection with the reference line of a perpendicular dropped from D until this line $KD'L$ meets verticals erected at the panel points C and B. The influence line may then be completed by connecting the points K and L with the ends of the reference line M and N, since it has just been shown that these portions are straight lines, and two points upon each of these lines have now been found. Ordinates above the reference line indicate stress of one kind, ordinates below stress of the opposite kind. The scale with which to measure the actual stress has as yet not been determined; but it is clear that if the stress is known for any position of the load such as B, the scale is immediately fixed.

The influence line for a unit load having thus been found, the position of a series of concentrations causing the greatest stress can be found precisely as in Art. 2; the loads having been placed in a trial position, the sum of the products of the ordinates of the influence line by the amount of the load placed over any ordinate may be found and compared to another trial position; the greatest sum will give the position of the loading for maximum stress, and by means of the proper scale, the stress itself. It is possible, however, by the aid of the influence line just developed, to deduce a criterion which will at once enable the position of the loads causing the maximum stress to be determined.

Art. 12. Criterion to Determine Position of Loading for Maximum Web Stress.

The web member CA of the truss shown in Fig. 9 will be chosen, and it will be supposed that the loads advance upon the bridge, along the lower chord, from right to left. It is at once seen, by inspection of the influence line, that in general no load must pass the panel in question, since loads in that portion of the truss to the left of the panel will always cause negative stress; the exact distance which the loading must advance into the panel is then the quantity which must be determined. Let l be the distance from the end of the span R' to the point D where a load if placed. causes no stress in CA; l' the distance from the right end of the panel to the same point D; x the distance of any load P from the end of the span; x' the distance of any load P from the right end B of the panel; δm the general value of the influence ordinate between R' and B corresponding to a unit load; $(m-m')$ the value of the similar quantity between B and C; a the value of m' at the point D; ΣP all the weights on the bridge; $\Sigma P'$ the weights on the panel BC, and S the stress in the member AC. Evidently

$$S = \Sigma Pm - \Sigma P'm'. \qquad (1)$$

From similar triangles there is found that $m = \frac{ax}{l}$ and $m' = \frac{ax'}{l'}$

Substituting these values, eq. (1) becomes:

$$S = a\left\{\frac{1}{l}\,\Sigma Px - \frac{1}{l'}\,\Sigma P'x'\right\}. \qquad (2)$$

If the train advances to the left by an amount equal to Δx, the stress becomes

$$S' = a\left\{\frac{1}{l}\Sigma P(x+\Delta x) - \frac{1}{l_1}\Sigma P'(x'+\Delta x)\right\}$$ and the change in the stress is therefore,

$$\Delta S = S' - S = a\left\{\frac{1}{l}\Sigma P\Delta x - \frac{1}{l'}\Sigma P'\Delta x\right\} \qquad (3)$$

assuming that no new loads advance upon the truss, and that no new loads enter the panel.

For a maximum or minimum $\Delta s = 0$; hence for this condition

$$\frac{l'}{l} = \frac{\Sigma P'}{\Sigma P}. \qquad (4)$$

This equation is a perfectly general equation of condition for finding a maximum stress, and is made applicable for finding the greatest counter stress, by substituting for l and l' the proper quantities measured from the left ends of the truss and panel.

In order that eq. 4 may hold, it will usually be found necessary to place a weight at the panel point B, and to consider only so much of it in the panel CB that may be necessary to fulfill the conditions of the equation.

This criterion may be used graphically in a manner similar to that shown in Art. 5. Lay off the weights P_1, P_2, etc., on a vertical line passing through N, beginning at the bottom with P_1 and on a strip of paper lay off the distances between the loads, beginning at the right with P_1. Let PE represent the total load ΣP on the bridge, P_2 being at the panel point B; connect D' with E by a straight line cutting a vertical erected at B or P_2 at F. If a horizontal line drawn through F intersects the load P_2 on the line NE the equation of condition is satisfied, and this will be one position of the loading, causing maximum stress. For, from similar triangles,

$$\frac{D'G}{D'N} = \frac{NH}{NE} \text{ or } \frac{l'}{l} = \frac{\Sigma P'}{\Sigma P}.$$

Application of the Criterion.

An application of this method for finding the maximum and minimum stress in the diagonal S_4 of the truss shown in Fig. 10 will now be made. The following are the required data:

Span = 264 feet; number of panels = 8; panel length = 33. feet; depth of truss at center = 42 feet; length of S_3 = 39 feet; length of S_1 = 31 feet; loading = E 40 of Cooper's specifications.

Following the methods of Art. 10 it will be found that D is that point where a load, if placed, will cause no stress in S_4, and this point is projected vertically downwards as D' upon the base line MN. It will be supposed that the loading has advanced upon the span from the right, and to such a point that wheel load 3 is at the panel point B; the number of concentrations on the span, as well as the position of each load, is easily found by laying off to scale on a strip of paper the distances between the loads, and moving this strip until wheel 3 is at the point G; the line MN shows this particular position of the loads. It should be noted that ten feet of uniform load are treated as one concentrated load, the effect of the latter being to act at the center of the ten-foot section. The amounts of the wheel loads are then laid off upwards in regular order on the vertical erected at the right end of the base line, extending from N to E. The points D' and E are then connected by a straight line and a horizontal FH drawn drawn through F, the intersection of $D'E$ with a vertical erected at G. Then, since FH intersects the load line in the load 3, the conditions of eq. (4) are fulfilled, and this position of the loading causes a maximum stress.

In order to determine the actual stress in S_4, it will then be necessary to find both the reaction at the left end of the span and the reaction at the left end of the panel; these quantities are easily found, both for this position and other positions which the loading may occupy from a reaction influence line $NSTU$ for the main span and a line VW, shown in the left-hand corner, for the panel length. These forces XY and $X'Y'$ are the only external forces acting at the left of the section passing through the members V_3, S_4 and L_3; therefore their resultant holds in equilibrium the stresses in these three members, and these stresses may be found by means of the method of Art. 9.

At this point, however, an approximation, involving but small error, and that on the side of safety will be introduced and consists simply in neglecting the panel reaction $X'Y'$; that is, instead of taking the resultant of these two external forces, which acts a little to the left of the point R, only the reaction XY at R is taken. The point A, which is the intersection of the lines of application U_3 and S_4 is then connected with the point R, which is the intersec-

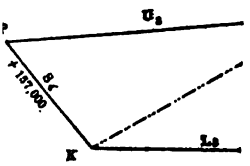
tion of the lines of application of L_3 and XY, and the force diagram $PRLK$ drawn, the line RL representing to a much reduced scale the ordinate XY found from the reaction influence line below the wheel load 1. By means of the proper scale, the maximum stress in S_4 is thus found to be a tension of 158,000 pounds.

In order to find the minimum stress, the maximun stress in the member S_4' situated in a corresponding position on the other side of the center of the truss, will be found. By means of exactly similar construction to that employed above, it is found that wheel load 2 at panel point C' will cause a maximum stress; the reaction is found to be $X''Y''$ and the stress by means of the polygon $R'P'K'L'$ at the right end of the truss is found to be a compression of 50,000 pounds. In order to avoid confusion between main and counter stresses, the diagrams for main stress should always be drawn at the left end, and those for the counter stresses at the right end of the truss.

As already noted, the values of the stresses found in this manner are not quite exact; in order to make them absolutely so, the effect of the small forces acting at the left end of any panel in question must be included and may be treated as if existing independently of the main reaction; the quantity thus found separately must be added algebraically to the stress previously found to make the latter exact. For instance, in the case of S_4 the quantity $X'Y'$ is equal to 6,500 pounds acting downwards at C; passing a section through U_3, S_4 and L_3 it is found that, due to $X'Y'$, S_4 sustains a compression of 7,000 pounds; the exact stress in S_4 is therefore $158{,}000 - 7{,}000 = 151{,}000$ pounds tension. The percentage of error involved in the approximation is never very large; the judgment of the designer must determine whether to apply the exact case or whether to make the approximation. Stresses in the other web members may then be found by similar methods of procedure.

There still remain to be determined the stresses in the chords; these stresses are found, precisely as in the case of trusses with parallel chords, by finding the maximum bending moments at the various panel points, and dividing these moments by the proper lever arms for the various chord members. For instance, to find the maximum stress in L_3 the maximum bending moment for the point A is divided by the distance AC, and the quotient is the stress in L_3. In this way all the live load stresses may be found; the

ISE OF INFLUENCE LINES



dead load stresses, as usual, are to be found by means of the ordinary force polygon.

The problem of finding the maximum chord stresses in trusses of that kind in which the center of moments for any chord member does not fall at a panel point or in a vertical erected at a panel point, and the problem of trusses with subdivided panels still remains to be considered.

THE LATEST PROGRESS IN SHAFT SINKING.*

By CHIEF ENGINEER RIEMER.

The recent period of financial expansion, coupled with the continued desire for increase in the production of coal, as well as the many recent developments of potassium salts, have within the last few years produced an unprecedented activity in shaft sinking. These conditions have naturally called forth earnest endeavors to improve and accelerate shaft sinking methods; yet, in spite of these facts and of many proposed improvements and numerous new patents, there have been practically no fundamental innovations possessing the elements of success. It is necessary, therefore, to confine ourselves to a discussion of the various advances which have been made in the methods already well known.

Considering first the usual method of shaft-sinking in hard ground, involving actual labor in the bottom of the shaft, accompanied by pumping of all water which may be encountered, we find that the main improvement consists in the increasing application of Tomson's device of bailing the water with the hoisting engine instead of pumping it. This has the great advantage that the entire apparatus is so suspended that it can be promptly hoisted out of the way, when the shaft is to be cleared preparatory to blasting, and, in conjunction with good administration, has produced results which formerly were rarely attainable. The daily progress quite frequently reaches 2½ meters (8.2 ft.) to 3 meters (9.8 ft.). Shaft No. 5 of the Potassium Works at Aschersleben was sunk 286.4 meters (940 ft.) in 252 days. During that time it was also completely timbered and equipped with guides for hoisting purposes.

---

* Translated by C. R. Corning and Robert Peele for SCHOOL OF MINES QUARTERLY, from the "Report of the Eighth General German Mining Congress at Dortmund," September 11–14, 1901.

From a depth of 18.6 meters (61 feet) to 216 meters (708 ft.), that is, a distance of 197.4 meters (647 ft.), the shaft was lined with tubbing, this portion being finished ready for hoisting in 176 days. The average progress to a total depth of 286 meters (938 ft.) was 1.12 meters (3.6 ft.) of completed shaft per day; the total cost, including tubbing, bolts, lead, concrete and wages, amounted to M. 1,750 ($437) per meter for the tubbed portion of the shaft.

The shafts of the Georgs-Marienhuette near Werne in Westphalia were put down through marls from a depth of 25 meters (82 ft.) to 459 meters (1,505 ft.), that is, a total distance of 434 meters (1,423 ft.) in nine months; making an average of 48.2 meters (158 ft.) per month; the maximum advance in one month being 60 meters (197 ft.). Inclusive of the passing through 10.6 m. (34.8 ft.) of quicksand and the safeguarding of this portion by means of tubbing, the total time consumed, from surface to the carboniferous beds at a depth of 580 meters (1902 ft.), was 20 months. Work was begun September 1, 1899, and finished May 2, 1901. The average progress for this great depth was consequently 29 meters (95 ft.) per month. At a depth of 460 meters (1,508 ft.), a flow of 150 liters (40 gals.) of water per minute was encountered, and at 555 meters (1,820 ft.) a second flow of 90 liters (24 gals.) per minute, between two beds of green sand. This latter occurrence rendered the sinking below that point materially more difficult than it had been above.

The method first employed on a large scale by Haniel & Lueg for certain shafts, and which consists mainly in omitting all temporary timbering and supporting the shaft walls by putting in the tubbing as quickly as possible, has been occasionally used to advantage. At the present time, shaft No. 2 of the Zollern mine is being sunk in this way.

In very difficult cases, that is, in ground which carries much water and is either solid or slippy, there are still only three accepted methods, which in their adaptability for various cases overlap more or less. These are: the old system of drop shafts, shaft boring on the line of the Kind-Chaudron method and the freezing method. The latter will not be considered in this paper.

The difficulties encountered in sinking have of late years been continually augmented by the adoption of greater shaft diameters as well as because of the constantly increasing depths, and the development of ore deposits covered by thick layers of quicksand, which were formerly considered to be unworkable.

The System of Drop Shafts.

The shafts being sunk at present near Kohlscheid, Eschweiler, Moers, Sterkrade and Holten, have each presented serious difficulties, which have been overcome by introducing the more useful of the recent improvements.

The sinking of Rheinpreussen Shaft No. 3, between 1892 and 1895, which was described by Bergrath Luecke in the *Preuss. Zeitschrift*, Vol. 49, forms an important turning point in the sinking of drop shafts, because of the fact that the management employed for the first time and with eminent success the device of forcing down the shaft walling by means of hydraulic presses connected with an accumulator. This method was advantageously employed later on in all important cases of a similar nature.

Hugo Shaft No. 1, near Holten, was sunk from a depth of 70 meters (230 ft.) to 170 meters (557 ft.) in 7 months, without change of diameter, by the Gutehoffnungshuette. In spite of its cast-iron walls being 70 millimeters (2.8 inches) thick, this shaft was unfortunately damaged by longitudinal fractures and was ultimately destroyed by external pressure. Many drop shafts, even small ones, have suffered similar deformation when put down to depths of only 30 meters (98½ ft.) and frequently had to be reënforced, after reaching bed-rock, by the installation of new tubbing.

Before proceeding further, a few remarks may be made on the probable causes of such damage, referring at the same time to the case of a small drop shaft which came to my notice in my capacity of an expert in court. In this case, investigation on the spot and the testimony of witnesses showed that the quality of the lining left nothing to be desired, and that its thickness was ample according to all previous experience. Nevertheless, the shaft was damaged in its lower portion by longitudinal fractures, and by buckling had lost its circular shape and acquired an irregular cross-section. This was all the more remarkable as the dimensions were so small, the diameter being but 4½ meters (14.75 ft.) in the clear and the depth 31 meters (101½ ft.).

In considering this case, but one solution was possible, viz.: that movements must have taken place in the ground outside of the shaft walls, the disturbance having been caused by the operation of sinking itself. The ground in question consisted of alternate loose layers of clean sand or more or less clayey material and hard beds of sandstone. Inrushes of the soft material in the bot-

tom of the shaft occurred several times during the process of sinking.

As to the cause of such inrushes, it is obvious that when a loose layer has been reached, and the bottom of the excavation is on a level or possibly deeper than the bottom of the lining, the unstable ground will gradually press inward from under the edge of the shoe. This is the more liable to occur because of the difference in specific gravities of the materials. In the shaft itself is water having a specific gravity of 1. The ground outside, saturated with water, has a specific gravity which may be assumed as 2. It would, therefore, appear that the pressure from outside is twice as great as the counter-pressure from inside, minus whatever portion of the difference may be counterbalanced by the friction in the outside ground itself.

When the conditions are such that the drop shaft will no longer sink readily, the operation may sometimes be facilitated by increasing the depth of excavation at the bottom of the shaft, and even undercutting the lower edge of the shoe; though of course such a proceeding distinctly invites an inrush of the ground from outside. As the sinking advances, the cavities behind the walls which are filled with water and no longer with rock or sand, will increase in size, especially upwards and laterally. This condition of affairs will continue until the cavities, which are naturally more or less irregular in shape, reach a more solid stratum. Comparative quiet may then be expected for a short period. Fig. No. 1 shows a shaft in this condition. Sooner or later, however, a catastrophe is almost certain to occur, by the giving way of the firm stratum forming the roof of the cavity. Water and mud or sand are then forced in large quantities into the shaft and the walls are subjected to a more less serious strain. At the same time the cavity is increased in size and may then break through to the surface, thus often endangering the surface plant. The shock of the falling masses which is transferred from the sloping sides of the cavity directly against the walls of the shaft is usually noiseless, as it occurs under water and the falling material is not solid. Nothing may be seen of the accident above ground except a sudden rise of the bottom and of the water level in the shaft itself.

Unfortunately it is impossible to calculate the various forces which the falling masses bring to bear on the shaft walls, since no facts are available on which to base estimates, and the conditions

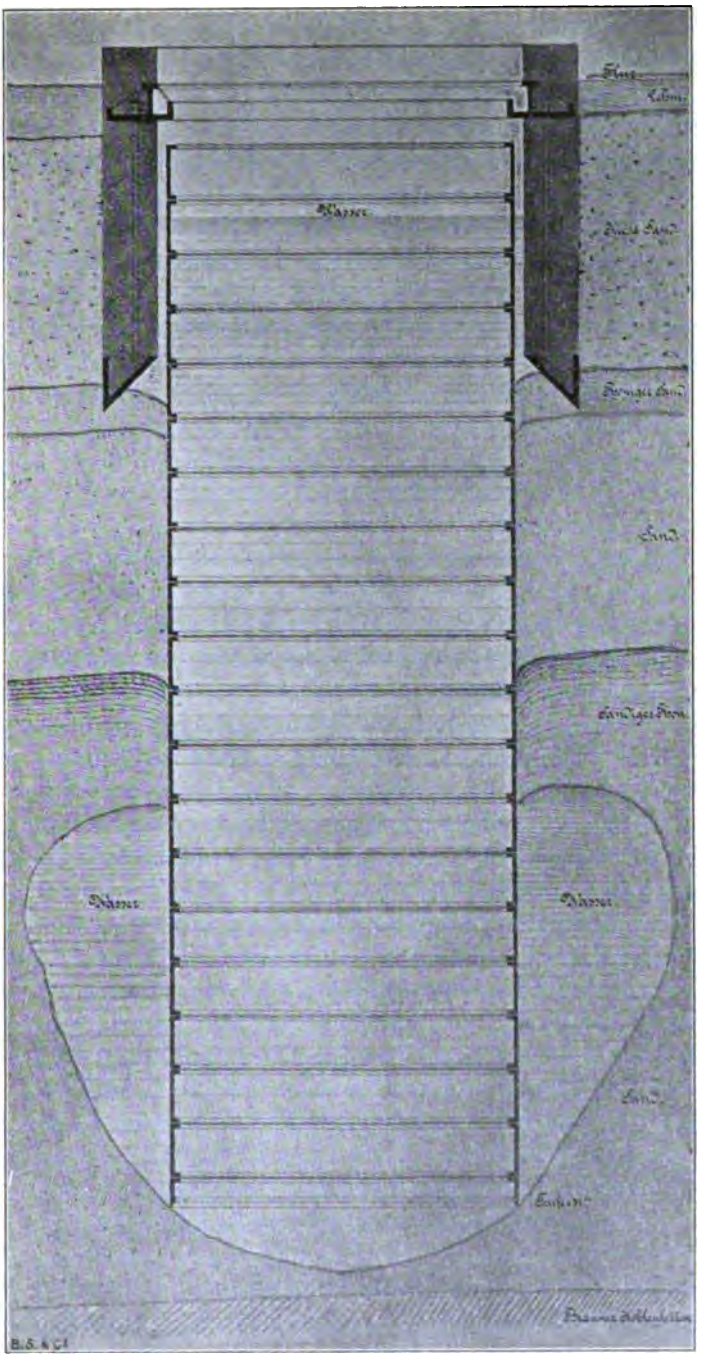


FIG. 1.

under which such unstable material moves in water are altogether unknown. Nothing better than an approximate estimate can be made. Assuming that the water-filled cavity be 4 meters (13.1 ft.) wide in a radial direction, by 10 meters (32.8 ft.) in height, and that the roof has dropped around one quarter of the circumference, which is say 26 meters (85 ft.), if the thickness of the caved ground be 5 meters (16.4 ft.) the volume would be 120 cubic meters (156 cb. yds.). Allowing for the excess weight of this mass above the weight of the water, it is found to be 120,000 kilos (132 tons), still using the previous data for the respective specific gravities. Assuming further that the period covering the drop be two seconds, as it occurs in water and not in the air, the total energy developed would be

$$\frac{120{,}000 \times 10}{2 \times 75} = 8{,}000 \text{ H.P.}$$

As already remarked, this figure is a very crude estimate; a large part of the shock will be absorbed by the inclined bottom of the cavity, and we are not dealing with a compact body. It is, therefore, probable that only a fraction of the above energy would be really expended against the walls of the shaft. However, no matter how small the estimated force may be, there will still remain sufficient to furnish an impressive idea of the possible strain on the shaft walls under such conditions. A further indication of the large forces involved in such occurrences is found in the fact that the bottom of the shaft and the water level frequently rise suddenly many meters. In one case which came under my observation, this rise amounted to 22 meters (72 ft.), and in another case where the level of the water was very low, the compression of the air above it forced the shaft scaffoldings to the surface, injuring a number of people.

With these facts in mind, it no longer seems surprising that in spite of the increased thickness and strength of wall (90 millimeters (3.6 inches) have already been used), damaged drop shafts still occur, particularly as the efficiency of the thicker walls is reduced by an accompanying increase of the diameter of the shafts themselves. Any further material increase in thickness is inadvisable, partly on account of the expense and partly because of the difficulty in handling the individual pieces. The use of some other material, for instance, cast steel instead of cast iron, would

be three times as expensive and not of much advantage. The relative strength of the metal is the main question, and cast steel for this kind of work is not much superior to cast iron. It is consequently essential that such falls as are referred to above should be prevented by taking care during the process of sinking that the lower edge of the shoe be always in unbroken ground, that is, kept as far as possible below the actual bottom of the shaft. This can only be accomplished by means of strong presses to force the wall downwards. Unfortunately, when sinking in soft material, the miner lacks any reliable check on the amount of ground removed. He is unable to tell whether or not some of the material has come from behind the walls of the shaft, as he has no safe guide as to the volumetric relation between the ground in place and the ground as dumped on the surface. It is for this reason that, although the danger may be diminished by applying hydraulic jacks, it can never be completely eliminated; and hence also arises the necessity for persistent attempts to increase the strength of the drop shaft itself.

It would appear that such increase of strength can be attained only by means of improved construction. The lines along which this should take place lie in an increase of the mass of the drop shaft and its inertia; if possible, however, without any increase in the weight of iron employed.

On the suggestion of General Manager Pattberg, a composite drop shaft of iron and masonry or concrete, was patented by Haniel & Lueg. Its essential feature is the interpolation of broad, stiff strengthening rings between the ordinary sections of lining. These are intended to prevent a deformation of the circular shaft. In the lower part of the shaft, where the danger is most serious, these rings are placed at, say, every 3 meters (9.8 ft.). Further up they are spaced respectively 4½ meters (14.7 ft.), 6 meters (19.7 ft.) or 9 meters (29.5 ft.). These wide rings project somewhat on the inside of the shaft beyond the flanges of the rings, imparting considerable extra strength. They are tied together by bolts, and the spaces between them are filled with masonry or concrete, so that the inner surface of the drop shaft becomes a smooth cylinder. This masonry itself forms a material factor in the strengthening of the shaft, supporting the iron walls and furnishing an advantageous increase in the weight.

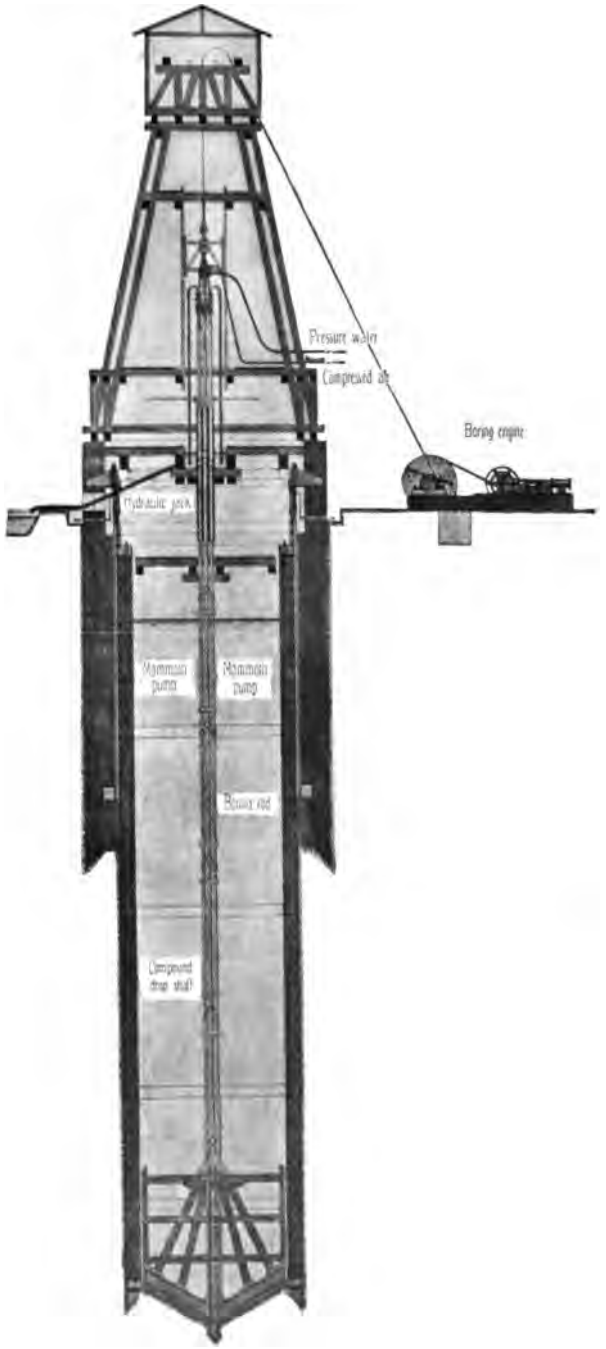
The walls of such shafts are naturally thicker than those com-

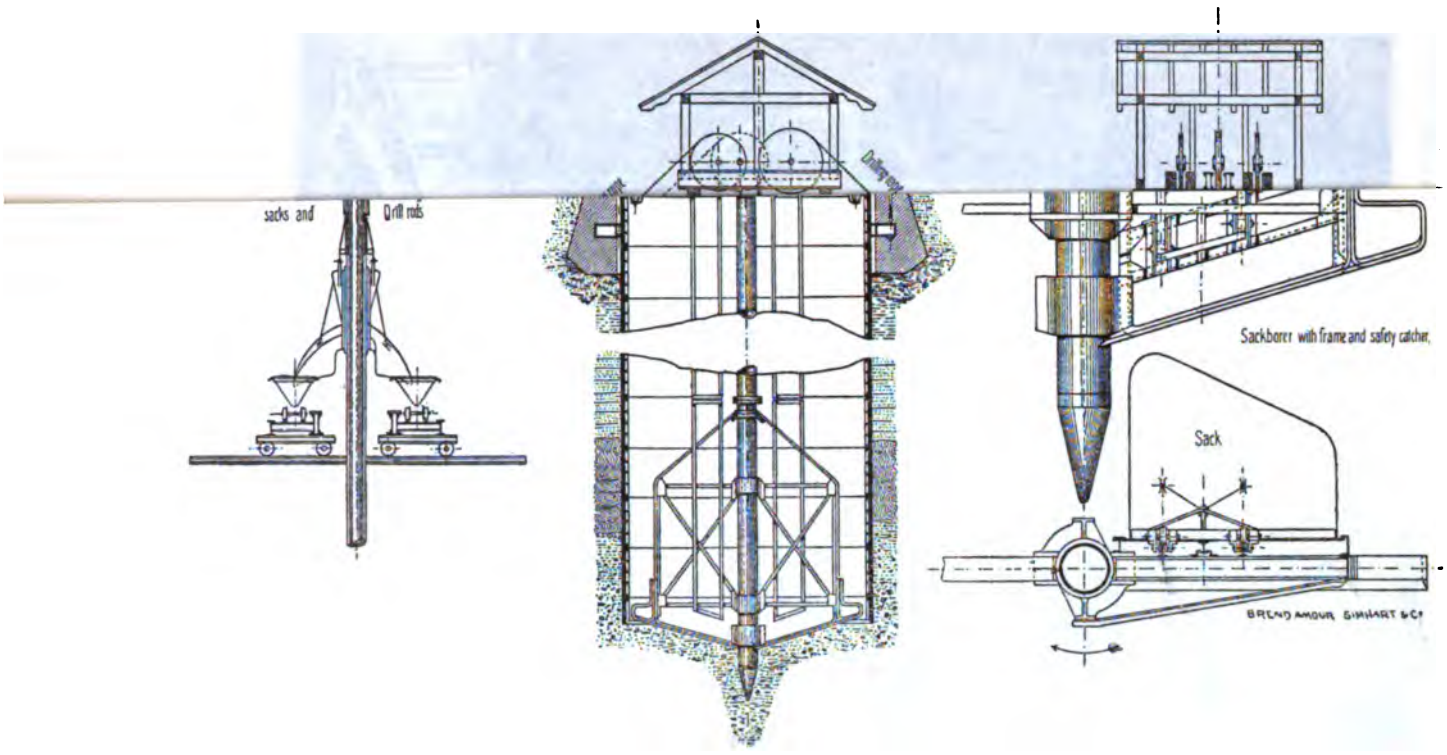
posed of ordinary iron rings, and, so far as thickness is concerned, occupy a place between shafts all of iron and those purely of masonry. While this increased thickness of the walls is disadvantageous, especially when great depths make the telescoping of several successive linings desirable, it is, however, a rule that these heavy drop shafts can be carried deeper than the ordinary iron ones. This process was adopted at Rheinpreussen shafts Nos. 4 and 5, as shown on Plate I.

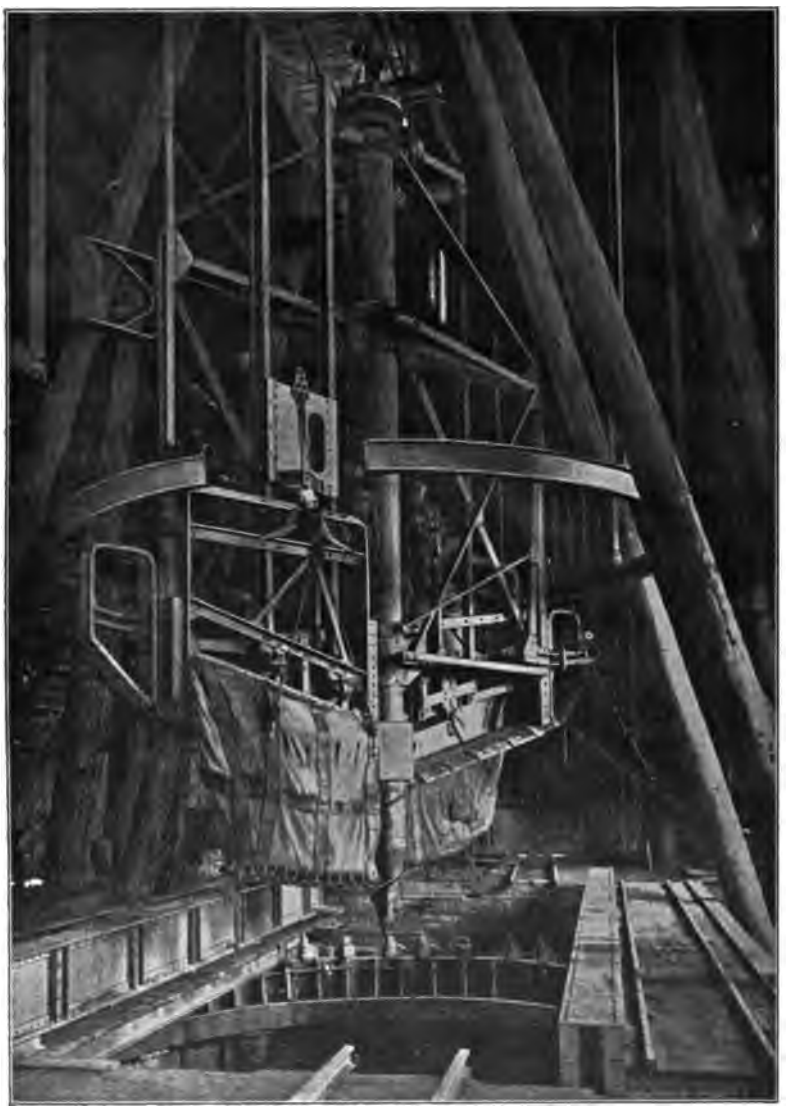
Conjointly with these improvements in shaft construction, attempts have been made to increase the amount of material hoisted in a given time. These were the more important, as experience shows that by forcing the drop shaft down, almost any desired progress can be obtained. Theoretically, the progress made is as rapid as can be equalled in the work of putting the lining rings in place, and as it is quite feasible with good management to put in three rings, equal to 4½ meters (14.7 ft.), in 24 hours, this may be considered as an easily attainable speed of sinking for drop shafts, providing the hoisting can keep pace with it. Unfortunately, we are still far from this ideal, although considerable progress has been made.

As to the various methods of excavation which depend on the use of the old sack borer, the dredge, the endless bucket chain or pumps run by water, air or steam, details may be omitted concerning the dredge and chain of buckets, because, so far as I know, no improvements in these directions have recently been made.

The old sack borer, which was always used when other methods failed, as it worked successfully although slowly in all kinds of soft formations, has recently been greatly improved by the devices introduced by Sessenberg & Clermont. The small efficiency of the old sack borer was due mainly to the fact that to empty the sacks the entire string of rods as well as the borer had to be raised to the surface. This process consumed much time and labor, and in deep shafts greatly reduced the capacity. Sassenberg & Clermont so modified the apparatus that the sacks could be hoisted to the surface by the engine without disturbing the borer and rods. This makes it possible, in sinking a deep shaft, to raise and empty the sacks in a few minutes where hours were formerly consumed. Plate II. shows the new borer as employed in the Adolfschaft at Eschweiler, a photographic reproduction of the borer and sacks being given also on Plate III. It is patented in Germany under


Pressure water
Compressed air
Boring engine
Hydraulic jack
Hammann pump
Hammann pump
Boring rod
Compressed drop shaft


sacks and
Drill rods
Sackborer with frame and safety catcher.
Sack
BRAND AMOUR SIMHART & Co



No. 96,015, and has been used with success both at Kohlscheid and at the Adolfschaft near Alsdorf.

Previous to this improvement, Jacobi in Sterkrade had recognized the defects of the old sack borer, and had constructed another (patent No. 95,941), which, although it worked on a similar principle, had no sacks attached. The loosened material is hoisted to the surface by means of a sand pump through the center of the hollow drill rods (see Figs. 2 to 4). The borer itself can thereforework uninterruptedly. This apparatus was devised for the Hugo and Sterkrade shafts, but was not used as the ground to be penetrated was found to be suitable for dredging.

The use of pumps for raising the loosened material and water has been adopted with increasing frequency. They work either as elevators run by water or steam, or are of the type of the so-called Mammoth pump. The operation of the latter is based on the fact that if compressed air is forced into a pipe, open at both ends, through a smaller pipe which runs down sufficiently deep below the water level, the air will rise in bubbles, and so create a fluid consisting of a mixture of air and water, the specific gravity of which is less than that of water alone. This mixture will then be forced upward by the pressure of the water outside of the exterior pipe and will be discharged at the top. If the compressed air be admitted continuously, the pump will remain in action and forms an extremely valuable apparatus for the elevation of water carrying sand, slimes, gravels, etc., as there are no valves or other moving parts subject to injury. This device is very old and was probably first suggested by W. Siemens. It has been built in several forms by Borsig in Berlin.* F. Honigmann, in Aachen, also took out a patent, in which the drill rods were utilized as a pump column. Plate I shows the arrangement as installed at the Rheinpreussen shafts Nos. 4 and 5.

A difficulty which is often encountered when drop shafts are used, and which necessitates care in deciding upon the proper diameter, is the tendency of the shaft to deviate from the vertical. Although this tendency can be reduced by employing hydraulic jacks and other safeguards shown in Plate II., it would neverthless be most desirable to eliminate it completely. The chief cause of the trouble is analogous to that which tends to produce deflection

* An adaptation of this principle is employed also in the well-known Pohle compressed air pump. (Translators.)

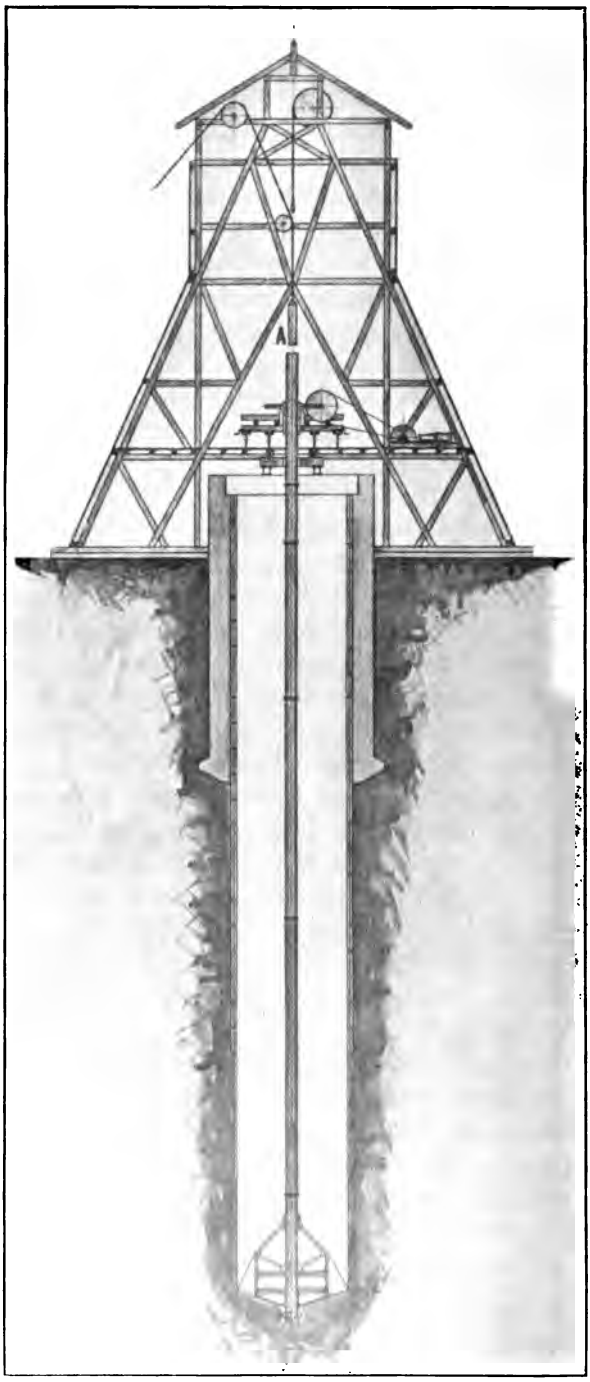


FIG. 2.

of all rotating drills. The claw dredge and the methods of sluicing in use offer no greater security that the shaft will be vertical.

As it is well known that the percussion drill is less likely to deflect from the vertical, Pattberg recently adopted this system for drop shafts, the bottom of the shaft being kept clean by using water under pressure and the cuttings or sludge removed by means of a compressed air pump. The drill is made as light as possible and is operated by means of rods actuated by a patent arrangement of oscillating drums. This process is similar to that which

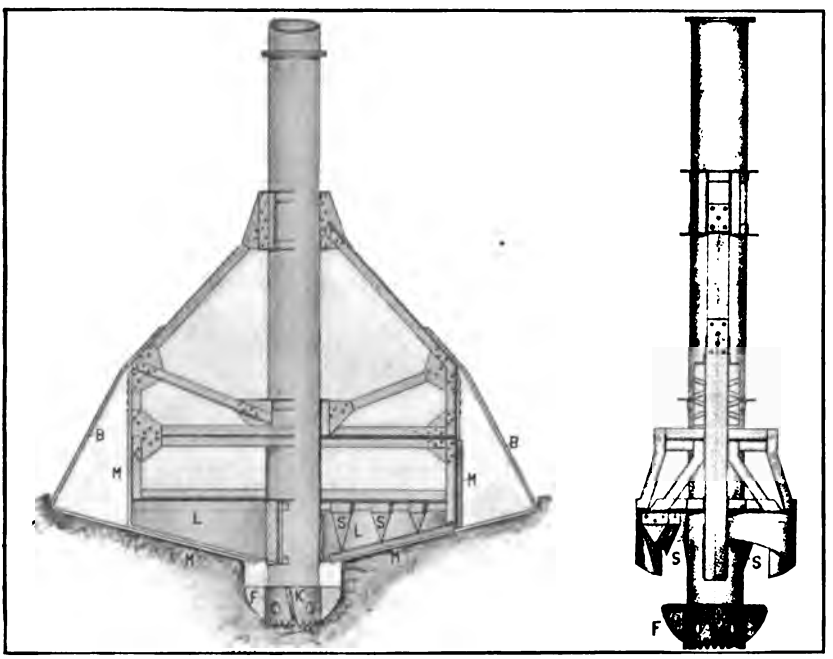


FIG. 3.

is in general use for boring holes of small diameter, the strokes being short and delivered in quick succession. The plant is well shown in Plate I., and a record of the results may soon be expected from shafts 4 and 5 at Rheinpreussen.

Honigmann's system of boring shafts, concerning which but few reliable data have so far been published, belongs to the same category. In reply to questions, Mr. Honigmann stated that at Limburg near Heerlen, two shafts, respectively 3.3 meters (10.8 ft.) and 2.8 meters (9.2 ft.) in diameter, had been put down to a depth of

97 meters (318 ft.) and lined with iron cylinders. Two other shafts, each 3.9 meters (12.8 ft.) in diameter, have been successfully sunk to a depth of 130 meters (426 ft.) at Carl near Limburg. They

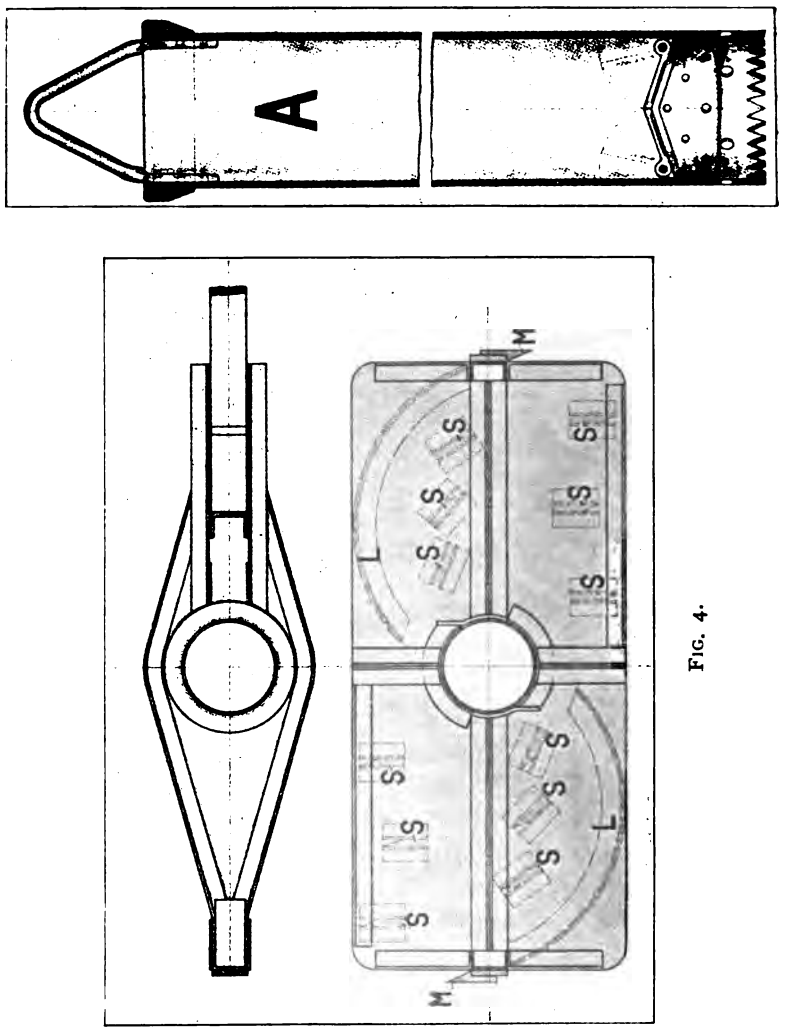


FIG. 4.

also were lined with plate iron cylinders of 15 to 20 millimeters (0.6 to 0.8 inch) thickness, with interior stiffeners of channel iron. At Nordstein near Aachen, a similar shaft 5.7 meters (18.7 ft.) in diameter, has been sunk to a depth of 77 meters (252 ft.) and similarly lined.

Of the more important works carried out by means of drop shafts with hydraulic jacks, the following, of which I give only the main data, may be of interest:

1. *Shaft Hugo at Holten, Belonging to the Gutehoffnungshuette.*

This was commenced with a drop shaft 7.2 meters (23.6 ft.) in the clear. It was first put down to a depth of 20 meters (65.6 ft.) below the level of the ground water, after which sinking in the bottom of the shaft was begun, and tubbing inserted measuring 6.72 meters (22.1 ft.) inside diameter. This was continued to a depth of 80 meters (262 ft.). The sump of the shaft was then concreted up to 65 meters (213 ft.) below the surface and the installation of an iron drop shaft, 6.08 meters (20.0 ft.) in the clear begun. The latter was carried down to a depth of 175 meters (574 ft.), and after filling the bottom with concrete, was pumped dry. The shaft lining buckled, however, and was ultimately completely ruined because of excessive pressure, the shaft finally being abandoned.

2. *Sterkrade Shaft, in the Same Field.*

This also was begun with a drop shaft 7.2 meters (23.6 ft.) inside diameter, and was forced down by pneumatic jacks for a distance of 17 meters (55.7 ft.); sinking was carried on by hand and masonry inserted in sections to a depth of 40 meters (131 ft.). The inside diameter of the masonry walling was also 7.2 meters (23.6 ft.). Work was then continued with an iron drop shaft 6.72 meters (22 ft.) in the clear to a depth of 80 meters (262 ft.), at which point the shaft stuck. A second iron drop shaft, 5.9 meters (19.3 ft.) diameter (telescoping inside of the first) was successfully completed to a depth of 132 meters (433 ft.), where the water was shut out in a clay formation. After the unfortunate experiences at the Hugo shaft, it was considered advisable to put in still another drop shaft, 5.1 meters (16.7 ft.) in the clear. This, too, stuck at a depth of 136½ meters (448 ft.), but the ground proved favorable and sinking was continued to a depth of 164 meters (538 ft.). The shaft was lined to 140 meters (459 ft.) with iron tubbing, and from there to the bottom with masonry. At present the guides and other shaft equipment are being installed, and it is intended to continue the sinking in the hard ground.

3. *Hugo Shaft No. 2 at Holten, in the Same Field.*

In order to replace shaft No. 1 which had collapsed, a new one was commenced similar to the above in all particulars except that,

instead of tubbing, masonry walling was put in in sections. The drop shaft had an inside diameter of 7.2 meters (23.6 ft.), and was sunk to a depth of 20 meters (65.6 ft.) below water level. From here on work was continued by hand, and masonry walling built in to a depth of 70 meters (229.5 ft.). At 61 meters (200 ft.) an iron drop shaft was built up on a concrete base. This had a diameter of 5.8 meters (19 ft.) in the clear and by the end of July last, attained a total depth of 162½ meters (533 ft.) at which point it refused to sink farther. It may be assumed that the shaft has reached a point where the water can be shut out, but to avoid unnecessary risk at such great depths, it has been decided to insert another and smaller drop shaft inside the present one. The material was hoisted in all three of the above shafts by means of a claw dredge, for which the ground was admirably adapted. For this reason the borer designed by Manager Jacobi was, as remarked above, not brought into use. This is to be regretted, as experience with this apparatus is up to the present time lacking.

In order to break through the concrete plug in the sump, a drilling plant, based on the Kind-Chaudron system, was used for the first time on the advice of Director Kocks. The steel shoe of the drop shaft always succeeded in clearing off the small shelf of concrete left by the borer. All necessity for using concrete in the bottom, which, at great depths and large shaft diameters, may prove unsatisfactory, is thereby reduced to a minimum.

4. *Shaft at Gemeinschaft, Belonging to the Consolidated Company in the Wurm District near Kohlscheid.*

This work was also begun with a drop shaft 6.7 meters (22 ft.) diameter, which was lowered to a depth of 18½ meters (60.7 ft.) below water level. Thereupon a first iron drop shaft, 6 meters (19.7 ft.) in the clear, was put in, and continued to a depth of 67½ meters (221 ft.). A second drop shaft, 5 meters (16.4 ft.) in the clear, afterwards reached a depth of 102 meters (334.5 ft.). At present a third shaft, 4.3 meters (14.1 ft.) in diameter, is being sunk, and it is hoped to reach hard ground at a depth of 140 meters (459 ft.). It is now down to 110 meters (361 ft.). The claw dredge was used at first, but as the ground is very fine grained and hard to excavate (though at the same time inclined to sudden inrushes), the old sack borer has been brought into use. In order to increase the efficiency of the latter, detachable sacks were used, although at

first with no great success. The entire apparatus, including rods, was buried to a depth of 13 meters (42.5 ft.) by a break in the shaft bottom; it was subsequently recovered by means of a Mammoth pump. The results obtained by this pump were so favorable that the management intends to continue experiments with it in future sinking, although at the present they are using the claw dredge.

5. *Adolfschaft at Alsdorf, Belonging to the Eschweiler Mining Company.* (*See Plate II.*)

At this point the ground water level is at a considerable depth below the surface. The work was consequently commenced by means of a masonry wall, which was not constructed on the principle of a drop shaft. It was extended to a depth of 32 meters (105 ft.) with a diameter of 7.7 meters (25.2 ft.) in the clear. The iron drop shaft inserted inside the walling has but 7.1 meters (23.3 ft.) clear diameter, and it is proposed to sink it to a depth of 90 meters (295 ft.). The diameters are so chosen that a second shaft of smaller diameter can be sunk inside the first, should it become necessary. At present the shoe of the drop shaft is at a depth of 60 meters (197 ft.) and work is progressing favorably by means of the sack borer with detachable sacks. This admits of hoisting a pair of sacks every 30 minutes, loaded with 1 to 1½ cubic meters (1.3 to 2 cu. yds.) of excavated material. It is therefore quite possible to excavate 48 to 50 cubic meters (62.5 to 65 cu. yds.) of ground per 24 hours, equivalent to an average of 1 meter (3.28 ft.) in depth of shaft. On August 6, when I visited the shaft, 1.2 meters (3.9 ft.) had been made in 24 hours, and the apparatus appeared to be working satisfactorily. The average monthly progress, including all delays, was 6 to 7½ meters (19.7 to 24.5 ft.)

6. *The New Shaft of the Thiederhall Company.*

This work also was started with a masonry wall, 8 meters (26.2 ft.) in the clear, and which it is proposed to continue to a depth of 25 meters (82 ft.). The inside iron drop shaft is to have a diameter of 6.4 meters (21 ft.) and will have to be sunk to a depth of 55 meters (180 ft.) to reach solid ground. Excavation is carried on by means of the claw dredge.

7 and 8. *Rheinpreussen Shafts 4 and 5, near Moers.*

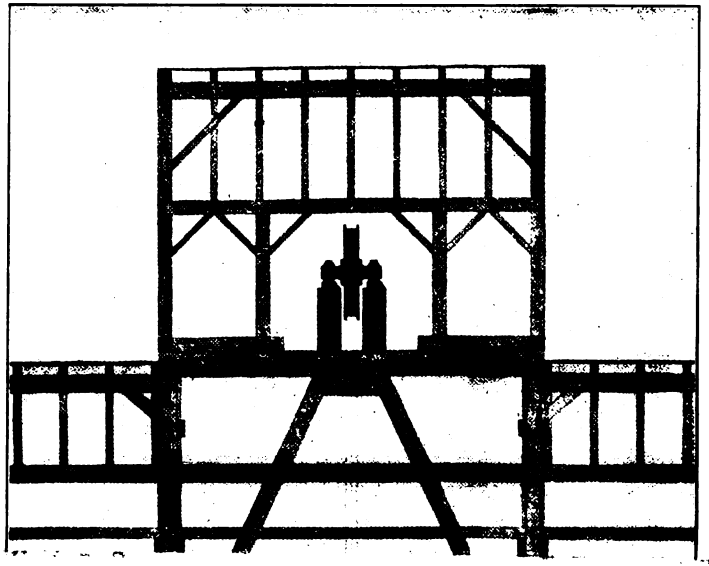
These two shafts, each of which must be sunk about 160 meters (524 ft.) to reach the carboniferous formation, were commenced

with drop shaft walls 8.9 meters (29.2 ft.) in the clear, reaching to a depth of 25 meters (82 ft.). Concrete plugs were placed in the bottom. After they had hardened, the rings to serve as a base for hydraulic jacks were built in, and the drop shaft narrowed to a diameter of 7.8 meters (25.6 ft.) by masonry built up on these rings, which served the purpose of supporting the guides and pressure ings. This work was carried out with such solidity that a pressure of 3,000 tons can be exerted if necessary. The composite shafts of iron and masonry which were then built inside of the drop shafts themselves, have 6½ meters (21.3 ft.) inside diameter, and are provided with unusually heavy shoes.

The ground is broken by means of a drill, which is so arranged that water under pressure can be fed to it through the hollow drill rods. This water flows out around the chisels near the bottom, stirs up the drillings and carries them away. At the lowest part of the inverted conical sump, two compressed air pumps, which are attached one on each side of the drill rods, raise to the surface the water and drillings. At the collar of the shaft an ingenious swivel coupling is provided for the introduction of the compressed air and water under pressure during the rotary movement of the drill. The drill itself is operated by a machine with oscillating drums patented under No. 104,158. To reduce shocks, it is also provided with a pneumatic buffer, patented under No. 105,931. The drill, etc., is suspended by a flat rope, which is carried over a sheave at the top of the headgear and is attached to the above-mentioned swivel coupling. The entire plant worked without trouble from the start. The apparatus is patented under No. 124,052. (Details are shown on Plate II.)

As already stated, all these shafts are arranged for using hydraulic jacks and accumulators, as well as rigid guide shoes working on the square tie bolts as guide rods. This latter arrangement is patented under No. 91,572 and has proven most satisfactory in maintaining the verticality of the shaft.

At present a considerable number of shafts of the very largest dimensions are being put down by the drop shaft method. Many more examples might be cited, the above having been selected either because of unusual dimensions, or as exemplifying noteworthy improvements in plant or method.



BEGINNING TO SINK THE TUBBING.

CONCRETE.

Shaft Sinking by Boring.

Interest in the boring of shafts by the Kind-Chaudron method was not awakened in Germany until General Manager Schultz Briesen described the sinking of the Dahlbusch shafts by this means. At that time this method had been successfully employed for 18 shafts in France, 12 in Belgium, 4 in England, 5 in Lorraine and 5 in Westphalia. All of the shafts put down in Westphalia belong to the Dahlbusch Company, which may consequently claim the honor of having been the introducer of this system. The depths of the various shafts vary from 88 to 117 meters (288 to 384 ft.). In most of them marls were encountered, which drilled easily and permitted of rapid work. Since that time, 22 more shafts have been sunk by this method in Germany. In none of these shafts was drilling commenced until a certain depth had been reached and the difficulties had so increased that all other methods had either failed or offered no prospect of success. The Kind-Chaudron system proved most successful in all cases, and up to the present time has always been unqualifiedly satisfactory, in that no shaft in which it was used has been abandoned. In one case alone was the boring not completely carried out. This was the Segengottes shaft at Mansfeld, it being demonstrated there that the system was unnecessary. General Manager Tomson deserves great credit for his advocacy of this system, since by its adoption he was enabled to complete shafts 1 and 2 at Gneisenau. In shaft No. 1 water was encountered, between 1882 and 1885, at a depth of 240.6 meters (787 ft.). In shaft 2 a similar flow was met with, between 1884 and 1886, at a depth of 244 meters (800 ft.). A closed top on the tubbings, allowing them to be shortened, was also used here for the first time. Both shafts were sunk to 105 meters (344 ft.) by hand, and then abandoned on account of large inflow of water.

Between 1884 and 1887, the Clotilde shaft at Mansfeld; between 1887 and 1889, shaft 2 of the salt works at Leopoldshall and shaft 1 at Thiederhall, near Brunswick, were put down by the Kind-Chaudron system. The latter shaft is particularly interesting, as the difficulties encountered were very great and the water-bearing strata continued down to the top of the rock salt strata. At that point for the first time the waters were successfully dammed back, an achievement which previously had not been considered possible in this formation.

In 1891 the commercial demands on the coal industry in Westphalia became more urgent, resulting in increased output and the sinking of correspondingly larger shafts. Up to this time circular drop shafts and tubbing linings could not be made larger than 3.65 meters (12 ft.) diameter in the clear, on account of the conditions prevailing in the iron works and on the transportation routes. This is probably one of the main reasons why the mining companies did not attempt boring or drilling if any other means were possible. Complying with the needs of the industry, the firm of Haniel and Lueg, at the suggestion of General Manager Tomson, devised a modification of their railroad equipment for the carriage of shaft tubbing, so that rings 4.1 meters (13 5 ft.) in the clear and 1.2 meters (39. ft.) in height might be conveyed through the normal section of the railroads.

By this means and by sectionalizing the outside ring of the moss-box (a proceeding also suggested by Tomson), it became possible to begin the tubbing of shaft 1 of the Preussen mine with a clear diameter of 4.1 meters (13.5 ft.) and that between the depths of 250 and 342 meters (820 and 1,120 ft.). The increased diameters and the continually greater depths of the shafts forced the management to drilling apparatus of stronger and better construction. In place of the old walking beam of oak reënforced with iron bands, a built-up iron beam was adopted, and although the other parts of the plant required but little change in general construction, it had to be materially strengthened. The diameter of the preliminary boring trepan was increased from 1.4 to 2.5 meters (4.6 to 8.2 ft.) and that of the enlarging trepan to 4.8 meters (15.75 ft.). Its construction was also modified in the sense of affording greater resistance to the constant shocks incidental to the work. The drill rods, which frequently had a length of 16 meters (52.5 ft.), were made 20 meters (65.5 ft.) long, in order to accelerate the operation of lowering and raising them. An important change was also made in the method of installing the tubbing. In the more shallow shafts, this was done with six winches which were placed in the shaft house or headgear, and were provided with rods for supporting the tubbing rings. For deep shafts this arrangement would have necessitated six sets of very long rods and would have been very expensive. At Preussen, therefore, after the tubbings had been fitted with their cover, this was provided with a sort of hook which was originally constructed by Chastelier, Chief

Engineer of the Societe Kind-Chaudron and had been in use at Ghlin. In this way the tubbings were lowered by means of the main drill rods and cable. Latterly, this hook has been used in connection with all large enterprises of this character.

Some of the details of a few of the more characteristic enterprises may now be presented.

Drilling of the Potassium Mine Shaft, at Jessenitz.

This shaft, begun in 1893 by the Mecklenburg Potassium Works, has probably consumed more time in its construction than any other sunk in recent years. The company has prosecuted the work with iron persistence and at an enormous expense. The shaft itself is of great interest because of the unusual difficulties encountered and the ingenious devices employed in combating them. The following formation had to be traversed:

0 to 19 meters (0–62.3 ft.), sand.
19 to 33 meters (62.3–108.0 ft.), mixed gravel; in part fine, in part coarse.
36 to 43 meters (108–141.0 ft.), gypsum with interbeddings of sand.
43 to 68 meters (141–223.0 ft.), gypsum; both hard and soft.
68 to 142 meters (223.0–466 ft.), hard gypsum.
142 to 146 meters (466–478 ft.), cavernous gypsum with clay.
146 to 153 meters (478–502 ft.), fissured sandstone.
153 to 270 meters (502–885 ft.), gypsum with anhydrite.
Below 270 meters (885 ft.), rock salt.

In the upper water-bearing strata, the Poetsch freezing method was used. After the ground had been frozen, sinking was begun and continued successfully to a depth of 75 meters (246 ft.). At this point the first wedging crib was placed and upon it German tubbing built in up to the collar of the shaft. Ordinary sinking by hand was then resumed. The second wedging crib was set at 89 meters (292 ft.) as the upper one allowed an inflow of 20 liters (5.3 gals.) of water per minute after the ground had thawed out. On this a second series of tubbing rings was started and carried up to the surface, entirely shutting out all water, so that the shaft was sunk dry to a total depth of 130 meters (427 ft.). From there on down the more fissured and water-bearing strata of rock were to be encountered, as had been demonstrated by the preliminary borings. As the entire apparatus for the freezing process was still on

hand, the management decided to utilize it in freezing the ground from 130 to 175 meters (427 to 574 ft.) in depth. The pipes for the freezing mixture were put down close to the shaft and at equal distances from one another. They were 170 millimeters (6.7 inches) inside diameter, by 10 millimeters (0.39 in.) thick and sunk to the total depth of 175 meters (574 ft.). The result was unsuccessful; in the subsequent sinking the frozen ground proved not to be water-tight and the shaft consequently filled with water. Attempts were then made to continue work by pumping the water, two large pumps being installed with a capacity of 40 cubic meters (10,500 gals.) of water per minute. Notwithstanding the outmost efforts, a depth of 150 meters (494 ft.) could not be reached. Although pumping was continued for several weeks with this large equipment, no other result was obtainable than that the water level, which at times stood but 8 meters (26 ft.) below the collar of the shaft, was lowered to 40 meters (131 ft.) below the same point.

After ten years of vain efforts, it was finally decided, in view of the impossibility of securing satisfactory progress, to finish the shaft by drilling. Unfortunately, the water had driven the crew out of the shaft sump before they could remove the tools. These, together with buckets, and other articles of iron and wood, had been left in the bottom, besides the freezing pipes, of which 35 meters (115 ft.) were still in the ground below the sump. The management was very desirous of removing these latter as they felt that they would be much in the way of drilling.

The work was commenced by concreting the bottom of the shaft for a height of 13 meters (42.5 ft.); this closed the water-bearing fissures. Thereupon all staging, pumps and supports were removed and an attempt made to withdraw the freezing pipes. This was a failure, undoubtedly because the pipes were damaged and broken. It was then attempted to sink bore holes around the pipes. This also was unsuccessful, because, as was discovered later, the pipes were not vertical, but very considerably out of line. After fruitless attempts lasting several months, it was finally decided to begin drilling and to remove the pipes in the ordinary course of the work. The arrangements were those generally in use. As might have been expected, the work was very unsatisfactory after passing through the concrete plug in the sump, partly because the sump of the shaft was not of even hardness over the total area, and partly because portions of the freezing pipes were stuck in the

shaft walls. In boring, these pipes were cut through lengthwise, but only partially, so that strips remained in the walls of the shaft and by their elasticity pressed against the trepan, frequently impeding its rotation, and by forcing it to one side caused the shaft to deviate from the vertical. These strips were finally removed, although with much difficulty, by means of saw-like teeth which were attached to the trepan, and it became possible to keep the shaft vertical.

From a depth of 175 meters (574 ft.), material improvement in the progress of drilling took place, this ground being below the bottom of the freezing pipes. Down to that point, 22,000 lbs. of wrought iron and steel in small pieces had been brought to the surface by the drilling operations.

Information obtained from the advance bore hole led the management to expect more compact gypsum from 175 m. (574 ft.) on downwards. They therefore hoped to dam back the water. In order, however, to be perfectly sure, the firm of Haniel and Lueg suggested that the ground be tested for water. With this end in view a pipe line was put down from the surface to the bottom of the advance bore, and its lower end filled for a height of 2 to 3 meters (6.5 to 10 ft.) with concrete. After this had set, the water was removed from the pipe and diamond drilling commenced inside. At a depth of 211 meters (692 ft.), water was again encountered, which rose to the top of the pipe. It was not quite certain, however, whether this water actually came from the rock itself or from a leak in the pipe. To decide this question, the drill hole which had reached 280 meters (918 ft.), was filled with concrete to a point 200 meters (656 ft.) below the surface, and after this had set, the pipe line was again pumped out. During this operation water could be lowered to a depth of 43 meters (141 ft.) without any apparent leakage. It was therefore plain that it was the ground itself which carried the water. These results having been elucidated, drilling was resumed, alternately with the smaller and larger trepans. After the advance bore had reached a depth of 252 meters (826 ft.) and the main bore 201 meters (659 ft.), further investigation of the ground was again instituted with similar results. The advance bore was therefore continued to 255 meters (836 ft.) and a test of the ground at this point, 6 meters (19.5 ft.) above the rock salt, was again made. Unfortunately, the ground immediately above the rock salt proved not only water-

bearing, but also much broken and inclined to cave. Under these conditions there was nothing to do but to continue the drilling some 20 meters (65.6 ft.) into the rock salt itself, and at that point to bed the moss ring for damming back of water.

On resuming drilling, rock salt was cut at 261 meters (856 ft.) and work was stopped after reaching a total depth of 287 meters (941 ft.). On testing the shaft by means of a wooden template to determine whether or not the tubbing could be inserted, the disagreeable discovery was made that the advance bore was filled to a depth of some 5 meters (16.4 ft.) deep with caved ground. It was to be feared that in letting down the tubbing rings, or while concreting after putting them in place, a caving of the shaft walls might occur and bring about a total failure of the work. In order to preclude such possibilities, it was determined to case the shaft with plate-iron cylinders from the rock salt upwards, that is, from a depth of 260 to 210 meters (853 to 689 ft.)

This casing could not be put in place in one piece. It was consequently cut in two, each part being 27 meters (88.5 ft.) long, and then lowered. The first portion was 4.756 meters (15.6 ft.) in diameter by 16 millimeters (0.63 in.) thick and weighed 62,500 K. (137,500 lbs). At a depth of 194 meters (636 ft.) the casing jammed, probably because of some small unevenness in the walls at this point. Moving the casing up and down did not overcome the difficulty, and it was therefore raised to the surface and again cut in two. It was now passed smoothly through the shaft and brought to rest at a depth of 263 meters (862 ft.) on the small annular shelf which had remained standing at that point. Further casing of the shaft was then abandoned as it seemed certain that the previously mentioned cavings had their origin in the ground immediately above the rock salt, which was now safeguarded by the casing put in place. The tubbing, which was 4.1 meters (13.5 ft.) in the clear, was now inserted and concreted in the ordinary way.

After the concrete had set, an attempt was made to pump out the shaft. It then became apparent that the water had not been successfully dammed back, as it flowed out through the openings in the equilibrium pipe. Soundings inside of this pipe proved that the space in the shaft bottom, below the false bottom of the tubbing, was filled with caved gypsum. It could not be ascertained whether this fall came from the ground above the casing and had broken loose either at the same time or just before the first concreting, and

had consequently nullified the result of that operation in the lower water-bearing strata, or whether on account of the steep dip and the undulating surface of the rock salt itself, the shaft might not have penetrated far enough into the latter, thus permitting the water to enter the shaft.

All attempts to bail the water failed; its level stood constantly in the equilibrium pipe at 50 meters (164 ft.) below the surface. The only remaining chance to complete the shaft lay in the installation of another smaller set of tubbing rings, and to put this in the shaft had to be sunk 30 meters (98 ft.) deeper, in order to dam back the water sufficiently to permit of the removal of the equilibrium pipe. The space below the false bottom of the tubbing was filled with concrete, which was lowered in buckets through the equilibrium pipe. After the concrete had set, the water which had entered through the moss box was shut off so that all water contained in the shaft itself was easily removed and the entire equilibrium pipe was taken out.

After completion of these preliminaries, the drilling apparatus was reinstalled and drilling resumed, the advance bore being made with a 2½-meter (8.2-ft.) trepan, and the enlargement with one of 3.95 meters (13 ft.) diameter. The drilling through the false bottom, which could not be entirely removed beforehand on account of the water which it dammed back, and which itself had a weight of 15,000 K. (33,000 lbs.), proceeded without incident. Within five months the shaft had been deepened 30 meters (98.4 ft.), so that drilling was again stopped at a total depth of 310 meters (1,017 ft.).

Tubbing 3.15 meters (10.3 ft.) diameter and 39 meters (128 ft.) high, was then installed without further trouble. Particular care was taken in concreting the tubbing, an arrangement being adopted for dumping all of the concrete buckets simultaneously in the bottom of the shaft. The lower 6 meters (19.5 ft.) of the shaft behind the moss box were filled with best quality of magnesia cement; the remaining portion with ordinary concrete. After the concrete had set, the shaft was pumped out, and found to be perfectly watertight, which facilitated the dismantling of the top and bottom diaphragms and the installation of the connecting tubbing rings. These operations concluded the work of shaft sinking, which had lasted 16 years, and ultimately proved successful. The actual boring was commenced March 6, 1894, at a depth of 141.3 meters (465 ft.), and the final removal of the water in the shaft took place

February 1, 1900. Consequently the drilling of 170 meters (557 ft.) of shaft required 5 years and 11 months, while the completion of the upper 150 meters (492 ft.) had consumed 10 years.

The Jessenitz shaft proved again most satisfactorily that water can be completely dammed back in rock salt itself, and that the success of such an operation is not due merely to the occurrence of various fortunate circumstances, as was assumed by many technical experts when the Thiederhall shaft was completed. For example, serious doubts as to the final outcome were expressed when the Beienrode Company struck water in their shaft on entering the rock salt, and they consequently decided to sink an entirely new shaft. Such doubts, however, may now be considered groundless, particularly as the shaft of the Potassium Works at Benthe has again demonstrated, under conditions similar to those prevailing at Beienrode, that water-tight connections can readily be made even in the rock salt.

Boring of La Houve, Victor and Adolf von Hansemann Shafts.

Between 1896 and 1898, the drilling of the shafts for the stock company La Houve in Kreuzwald, also the Victor in Rauxel and the shafts for the Adolf von Hansemann Company, followed the work described in the previous paragraphs. Both at Victor and Adolf von Hansemann, tubbing of 4.4 meters (14.4 ft.) diameter were used for lining the shafts. Transportation of these large rings was possible only through the courtesy of the railroad management in Essen, which permitted a small lowering of the grade on the permanent roadway pending the transportation of these pieces.

At Adolf von Hansemann, the drill work in shaft No. 3 was preceded by rather interesting attempts to sink by other means, which proved that when the difficulties are really serious the method of drilling is always the cheapest in the end. Shaft No. 1 was begun in 1873 in the ordinary manner, and with endless trouble and expense was sunk to a depth of 230 meters (754 ft.) in 13 years. The enormous flow of water in the lower part was ultimately the cause of such insuperable difficulties that in 1886 all work was suspended. In 1888, shaft No. 2 was started 200 meters (656 ft.) to the south of shaft No. 1. The company was fortunate in this case, as the flow of water encountered was not too great to be handled with pumps. The maximum flow amounted to 7 cubic meters (1,850 gals.) per minute, and caused so much trouble that

it was five years before the shaft reached the carboniferous strata.

After completing shaft No. 2, work was resumed in shaft No. 1, supplementing the previous installation with the pumps used in shaft No. 2. No. 1 was undercut from No. 2 by a drift and a raise put up part way from the latter. The drift was then closed with a strong masonry dam provided with a pipe for tapping off the water and so regulating its flow towards shaft No. 2. Finally, a drill hole was put down in the bottom of shaft No. 1 to the lower drift.

Shaft No. 2 was supplied with direct-acting lift pumps. In order to make the operations perfectly safe, these were replaced by force pumps of a capacity of 10 cubic meters (2,640 gals.) per minute.

As an auxiliary, the large Woolf pump at shaft No. 1 could be used in addition to the pumps at shaft No. 2, thus providing for a total maximum flow of 15 cubic meters (3,960 gals.) per minute. There was also a small underground pump which could be utilized at shaft No. 2.

This entire equipment was barely able to pump No. 1 shaft dry, and as a further attempt at sinking resulted in a flow of 40 cubic meters (10,570 gals.) of water per minute, the shaft was finally abandoned.

On August 8, 1894, shaft No. 3 was begun, some 200 meters (656 ft.) north of shaft No. 1. The formation was approximately the same as in shafts 1 and 2, viz.:

From 0–7.5 meters (0–24.6 ft.), quicksand.

From 7.5–221.5 meters (24.6 ft.–727 ft.), green marls.

From 221.5–225 meters (727 ft.–738 ft.), upper green sand.

From 225–251.5 meters (738 ft.–828 ft.), white marls.

From 251.5–254.5 meters (828 ft.–835 ft.), lower green sand.

From 254.5 meters (835 ft.) down, carboniferous strata.

In the layer of quicksand above the marls, a drop shaft was started. Work was carried on in the ordinary way and the small amount of water which flowed in from the upper portion of the marl was shut out by means of German tubbing to a depth of 45 meters (143 ft.). From there on down masonry was put in.

At 190 meters (623 ft.) below the surface a fissure was encountered carrying 1.5 cubic meters (396 gals.) of water per minute. As shaft No. 1 at this depth had cut a particularly wet fissure, an increase of water was to be expected. Sinking was temporarily discontinued, therefore, and a drill hole put down to a drift driven

on the level of the airway at a depth of 273 meters (895 ft.). This drill hole was 230 millimeters (9.2 inches) in diameter and was successfully completed in six weeks. On resumption of work in the shaft, the flow of water increased so rapidly that in a short time the drill hole was unable to carry it off, and the management was obliged to increase its diameter to 270 millimeters (10.8 inches).

The shaft was then deepened another .5 meter (1.6 ft.) when work had to be stopped, as the flow of water exceeded 22 cubic meters (5,800 gals.) per minute and drowned out all provisions made for its removal. Before abandoning work in the sump, the air pipe and other apparatus in the shaft were removed, the bottom cleaned out and the door in the masonry dam in the lower drift closed.

Preparations were then begun above ground for the use of the Kind-Chaudron method. The construction and equipping of the drill tower, and installation of other drilling apparatus, consumed 3½ months.

On August 10, 1896, drilling was commenced with a 2.5-meter (8.2 ft.) trepan at a depth of 195.35 meters (640 ft.), the water level standing at 53.4 meters (175 ft.) below the surface. The work was completed December 8, at a depth of 255 meters (836 ft.), in solid carboniferous formation. About 60 meters (196 ft.) of shaft was bored, therefore, in four months; the average daily progress including all delays being .5 meter (1.64 ft.) and the maximum advance per month 18.22 meters (59.8 ft.). On December 18, 1896, work with the enlarging trepan, of 5.02 meters (16.4 ft.) diameter, was commenced at a depth of 195.5 meters (642 ft.). The work was completed November 19, 1897, at a depth of 253 meters (830 ft.); 58 meters (191 ft.) having been drilled in 11 months, equivalent to an average progress per 24 hours of 0.186 meter (0.6 ft.). The maximum advance per month was 7.8 meters (25.6 ft.). From December 19, 1897, to January 2, 1898, the apparatus was dismantled and preparations made for putting the tubbing in place. This consisted of 57 rings, 4.4 meters (14.4 ft.) in the clear, 1.2 meters (3.9 ft.) high and 68 to 86 millimeters (2.7 to 3.45 inches) in thickness.

The installation of the tubbing was commenced January 2, 1898, and finished March 4. Between March 15 and April 15 the concreting was completed. After six weeks, the work of pumping out the shaft was commenced and on the 21st of June the moss-box was

laid bare, thus proving that the water had been successfully shut out. The setting of the connecting tubbing rings occupied four weeks, so that on July 20, 1898, drill work was concluded and ordinary shift sinking in the sump could be resumed. From the beginning of the drilling to the beginning of sinking in the sump, 22 months were consumed, so that the average progress per month was 2.73 meters (8.95 ft.).

Shaft Drilling at Kaiseroda, Royal Salt Works at Friedrichshall and the Mecklenburg Company, Friedrich Franz.

In 1897 three shafts were put down by this method, viz. : At Kaiseroda in Thuringia, at Friedrichshall and near Luebtheen.

The Kaiseroda Company commenced sinking their shaft near Salzungen on the Werra; as usual, with manual labor in the sump and pumping the water which was encountered. In its upper portion the shaft was 5 meters (16 4 ft.) in diameter and was successfully lined with masonry to a depth of 34.8 meters (114 ft.). From this point downwards English tubbing was installed. The preliminary bore hole showed the following sequence of strata to be passed through:

From 0–2 meters (0–6.56 ft.), surface soil.

From 2–120 meters (6.6–394 ft.), buntersandstein.

From 120–166 meters (394–544 ft.), crumbly slates.

From 166–176 meters (544–576 ft.), extremely wet and slabby dolomites.

From 176–205 meters (576–672 ft.), variegated clays with stringers of gypsum.

From 205–207 meters (672–679 ft.), gray rock salt.

From 207–219 meters (679–718 ft.), anhydrite with rock salt.

From 219–225 meters (718–738 ft.), reddish clay sands.

From 225 meters (738 ft.) down, white rock salt.

The flow of water varied as follows:

At 8 meters (26.2 ft.) depth, about .5 cubic meter (132 gals.).

At 34.8 meters (114 ft.), 1 to 2 cubic meters (264–528 gals.).

At 44.3 meters (145 ft.), 3 cubic meters (792 gals.).

At 60.5 meters (197 ft.) 4 cubic meters (1,056 gals.).

At 80 meters (262 ft.), 5 cubic meters (1,320 gals.).

At 114 meters (374 ft.), 17 cubic meters (4,480 gals.).

When the shaft reached the crumbly slates the sinking proceeded well, as the larger portion of the water was successfully dammed

back by means of a wedging-crib at a depth of 129.6 meters (425 ft.). The next wedging crib was put in at 146 meters (479 ft.), the English tubbing being continued. When sinking was resumed, however, water broke forth again at 148 meters (485 ft.), and though three pumps were installed they were unable to keep pace with the inflow. It appeared furthermore that the ground around the bottom of the shaft was intersected by fissures carrying sand, which was washed into the shaft sump by the water and gradually filled it up. It became necessary to stop pumping, as it was quite evident that the continued removal of the sand from the fissures would ultimately lead to cavings, which would endanger the tubbing already in place.

Although the ground was not very favorable for the use of the Kind-Chaudron system of sinking, since the walls of the shaft would have to be prevented from caving by a lining, it was decided, nevertheless, to adopt this system, as no other appeared to offer any prospect of success.

In the beginning of May, pumping was stopped. The material in the sump was taken out as far as possible and the bottom of the shaft filled with concrete to a height of 8 meters (26.2 ft.). After this had set, the water was pumped out and all obstructions, such as pumps, beams, platforms, etc., removed from the shaft. On August 16, 1897, the preliminary work was so far advanced that drilling could be commenced. For the advance bore a trepan of 2.5 meters (8.2 ft.) diameter, and for enlargement, one of 4.83 meters (15.85 ft.) were decided upon. The latter was made as large as the tubbing would permit on account of the prospective lining of the shaft. The concrete plug in the bottom was drilled through between August 16 and September 10 by means of the enlarging trepan, and the advance bore was begun at a depth of 147.55 meters (484 ft.). On November 6 this work had reached a depth of 167.24 meters (549 ft.). The material traversed consisted of blue and red clays which, when dry, are very hard, but in a wet condition, swell and shift. In October, cavings were noticed, but as it was assumed that they had occurred in the walls of the advance bore, they were deemed of minor importance. Early in November, however, the bottom of the bore was filled to a height of 1.5 meters (4.9 ft.), whereupon the enlarging trepan was lowered, and it was found that it did not reach the former shelf left at 147.5 meters (484 ft.). It was consequently evident that this shelf was

covered with caved material which must have come from the sides of the enlargement, which therefore would have to be lined.

A plate iron cylinder 4.73 meters (15.5 ft.) inside and 4.81 meters (15.8 ft.) outside diameter, by 18 meters (59 ft.) high and weighing 65,000 kilos (143,000 lbs.), was then put in place. This cylinder consisted of riveted plates, 22 millimeters (0.9 inch) thick. The lower edge was sharpened like the shoe of a drop shaft; the upper edge being somewhat flattened, so that it could be eventually forced down by weighting. The work of putting in this lining was commenced January 15, 1899, and after it had reached the bottom, the clearing out of the advance bore was begun with the small trepan. The original sump of this work, at 167.2 meters (548 ft.) was again reached on the 4th of March. The bottom of the casing was then lowered by alternate use of the large and small trepans to a depth of 164 meters (538 ft.) and there left standing. A second casing was not considered necessary for the moment, as the ground appeared to be harder. After drilling had reached a depth of 194 meters (636 ft.), however, and renewed cavings had taken place in the shaft, a further casing had to be considered. The management thought that the caving had taken place in the walls immediately below the first casing, but as the ground here was hard, it would be well adapted to the holding back of the water. As the bottom of the bore was now quite close to the rock salt, and the management had definitely concluded not to place a moss-box in the rock salt itself, it was decided, on the assumption that a height of 15 meters (49.2 ft.) of free ground, without casing, would be sufficient to secure a good connection by means of concreting, to consider the drilling as finished and to install a further casing, suspending it by four ropes in such a way that the lower edge would be 15 meters (49.2 ft.) above the sump of the shaft, that is, at a depth of 178 meters (584 ft.). A casing cylinder of 4 meters (131 ft.) in length, was accordingly procured. On lowering it into place, it entered about .5 meter (1.6 ft.) into the lower end of the first cylinder, and was held in this position by four flat ropes, 100 millimeters by 10 millimeters (4 inches by 0.4 inch) in cross-section.

After clearing the shaft of all caved material, and on completion o the arrangements for lowering the permanent tubbing, it was discovered on November 10 that the sump had again filled and that the shaft would have to be cased all the way down.

The third casing was made 4.43 meters (14.5 ft.) in the clear,

and 4.478 meters (14.6 ft.) outside diameter; it was 19.5 meters (64.0 ft.) long and weighed 53,125 kilos (116,500 lbs.). On February 1 work was started to put this in place. It stuck on the 7th of the month at a total depth of 191.35 meters (627 ft.). As the sump, however, was at 194.37 meters (637 ft.) this showed that there were 3 meters (10 ft.) of caved ground on the bottom, which was promptly removed by means of the drill and sand-pump. In order to secure the necessary free ground for making the concrete connections, the sump was lowered by drilling to 203.5 meters (667 ft.).

The subsequent work proceeded without further interruption. All of the drilling apparatus was removed and on May 17 the installation of the permanent tubbing commenced. By June 5 the tubbing reached the bottom of the shaft, and the concreting was finished on July 6. From the 15th to the 26th of August the water was pumped out, and the top and bottom diaphragms of the tubbing removed. September 1 sinking was begun in the bottom of the shaft below the moss-box, soon resulting in an inflow of about 250 liters (660 gals.) of water per minute. In order to avoid interruptions by water in the continuation of the work, a Tomson bailing apparatus was installed. This took four weeks. Fortunately, on resuming work, it was discovered that the permanent inflow was only about 15 to 20 liters (4.2 to 5.3 gals.) per minute. From October 1 to November 11, 6.26 meters (20.5 ft.) were sunk by hand to the anhydrite. This distance was lined with tubbing which ultimately entirely cut off the flow of water.

By the Kind-Chaudron system, 70 meters (230 ft.) of shaft were completed in 27 months. The time might have been materially reduced had the casings been on hand when they were required. As they always had first to be ordered when needed, and as the work had to be stopped until they could be put in place, considerable time was lost. Further losses of time were incurred by the repeated drilling through material which had caved into the shaft and by the installation of Tomson's bailing apparatus, which, after all, was not required. The result of the drilling operations cannot be considered as otherwise than satisfactory, after making due allowance for the above conditions.

The work at the shaft of the Royal Salt Mines at Friedrichshall, near Jagtsfeld, which was drilled during the years 1897 to 1899, is noteworthy because here also drilling operations were not com-

menced until it was plainly seen that no further progress could be made by ordinary methods of sinking, in spite of active pumping which lifted as much as 30 cubic meters (7,592 gals.) of water per minute. Drilling commenced at a depth of 96 meters (315 ft.) and was finished at 116.9 meters (383 ft.). The average progress with the advance trepan was 0.54 meter (1.8 ft.) and with the enlarging trepan, 0.2 meter (0.65 ft.) per 24 hours. The tubbing was 4.4 meters (14.4 ft.) in the clear, and was transported by boat on the Rhine and Neckar.

In depositing the concrete back of the tubbing rings, six water-tight buckets were used, the valves of which were held in place so tightly by mechanical means that they could not be released when the bucket had reached the point of discharge, except by force. The six hoisting ropes belonging to these buckets were wound on the two multiple drums of the hoisting engine, each in its special groove. The twelve guide ropes for the buckets were wound on the drums of a separate stream winch. These various ropes were conducted to their respective points of support above the shaft by means of guide sheaves.

The arrangement permitted of raising and lowering the buckets, and the adjusting of the length of the guide ropes; each by a single machine and with much exactness. The improvement was the result of experience gained from experiments made on concreting by the methods heretofore in use. It was found, firstly: That if the concrete buckets were not water-tight, the rather fluid concrete necessary for this work was lost while lowering it down the shaft to the place where it was needed. Secondly: That in lowering individual buckets by means of a rope and brake, the point of discharge was left entirely to the judgment of the man at the brake and could not always be definitely determined. Furthermore, that when the valve of the bucket was loose, but a portion of the load actually reached the point of discharge. Thirdly: That the success of the concreting, which is one of the most important parts of this method of sinking, depended mainly on the certainty of being able to discharge the buckets at the correct point, and in such a manner that vortex movements of the water were reduced to a minimum and the concrete itself required to traverse the shortest possible distance in the water.

The operation of shutting out the water in this shaft was concluded with entire success.

Preussen No. 2 and Scharnhorst Shafts.

In 1897 drilling by the Kind-Chaudron process was begun at shaft No. 1 of the last-named company. This shaft was commenced in 1873 but had been abandoned after attaining a depth of 117 meters (384 ft.).

In the same year shafts 1 and 2 of Preussen No. 2 colliery were completed by drilling. Shaft No. 1 had been begun in the seventies of the last century, but after attaining a depth of 233 meters (763 ft.). it was abandoned on account of the large flow of water. It was drilled from a depth of 233 to 372 meters (764 to 1,222 ft.). shaft No. 2 of the same mine being sunk in a similar manner from 260 to 368 meters (853 to 1,206 ft.). Up to the present time these are the deepest shafts sunk by the Kind-Chaudron system.

The tubbing of shaft No. 1 is 4.1 meters (13.4 ft.) in diameter by 152 meters (498.5 ft.) in depth, and consists of rings varying in their thickness between 65 millimeters and 95 millimeters (2.6 inches and 3.8 inches). The weight of the entire lining, with all appurtenances, is 1,560,532 kilos (3,520,000 lbs.).

At shaft No. 2 the tubbing is 4.4 meters (14.4 ft.) diameter by 118 meters (387 ft.) in depth. The rings are 75 millimeters to 105 millimeters (3.0 inches to 4.2 inches) in thickness, with a total weight of 1,370,700 kilos (3,020,000 lbs.). The bottom diaphragm alone weighs 22,000 kilos (48,500 lbs.), and is of cast steel.

Drilling of the Grand Duke of Saxony Shaft near Dietlas.

This shaft is still in hand, and it is proposed to sink it considerably deeper, as the damming back of the water will probably not be possible short of a depth of 400 meters (1,310 ft.).

Shaft Sinking of the Benthe Stock Company, Formerly Known as Walmont, Hanover.

Shaft Hermann of this company was started April 5, 1899, about a kilometer from the village of Benthe. The preliminary boring had shown the following cross-section to be penetrated :

From 0–4 meters (0–13.1 ft.), surface soil.

From 4–33 meters (13.1–108.2 ft.), red clay, dry and very greasy,

From 33–85 meters (108.2–279 ft.), red and blue clays with various layers of sandstone.

From 85–170 meters (279–558 ft.), red and gray marls with stringers of gypsum.

From 170 meters (558 ft.) on downward, rock salt.

By May 30, the shaft had reached a depth of 33 meters (108 ft.). all work having been done by hand. After installing a hoist. sinking was resumed and proceeded so rapidly that rock salt was struck on the 17th of October at a depth of 163 meters (534 ft.). At this point, trouble was encountered in the shape of small flows of salt water, which showed themselves on the top of the rock salt. These carried 29 per cent. of salt and increased hourly so that the pumps, which had a capacity of 4 cubic meters (1,056 gals.) per minute, were finally unable to keep pace with the inflow. The handling of this water with larger pumps was not considered feasible by experts on account of the fact that the salt solution would gradually leach out the surrounding ground. The Kind-Chaudron system of drilling was therefore recommended, particularly as the results of work at Jessenitz had been so satisfactory.

Towards the end of October, this work was determined on, and the firm of Haniel and Lueg commissioned to carry it out. When the firm took charge of the work, the shaft had been lined with masonry from surface to a depth of 130 meters (426 ft.). Between that point and 163 meters (534 ft.) the provisional equipment was still in place. The inside diameter was 5 meters (16.4 ft.) The bottom of the shaft was quite uneven and had to be leveled by a concrete plug some 4 meters (13.1 ft.) deep to give the drill a good working surface to start on. This preliminary work was finished early in March.

The drill was then lowered in order to test the bottom. It stuck at a depth of 156 meters (512 ft.), or 6 meters (19.7 ft.) above the top of the concrete, and investigation showed that the bottom was filled with clay, which must have come from the portion of the shaft between 130 and 163 meters (427 and 535 ft.), that is, from below the permanent masonry. This fact demonstrated that cavings from this ground would almost unquestionably be repeated, and that they could only be prevented by a provisional casing of this portion of the shaft. To be perfectly sure, however, that the temporary timbering would really not be able to hold back the ground, the management decided to await further proof and at once to drill into the underlying rock salt with the full cross-section of the shaft. The clay in the bottom was therefore removed

with a sand-pump, the large trepan lowered and at 157 meters (515 ft.) a more solid bottom was reached. On April 25 the large trepan reached a depth of 166 meters (544 ft.) and was therefore entirely in the rock salt. Up to this time the sand-pump had always brought up a mixture of clay and rock salt, any serious caving of the clay walls not having been noticed.

On April 25 drilling with the small trepan was resumed and continued to a depth of 181.4 meters (595 ft.). During this work clay and a mixture of clay and rock salt was brought up, the clay preponderating. This of course demonstrated that the temporary timbering was unable to support the walls, and a casing was considered indispensable. On May 11, therefore, it was decided to put in a casing 4.9 meters (16.1 ft.) in the clear, 20 millimeters (0.8 inch) thick and 35.5 meters (116.2 ft.) long, as soon as drilling should have been concluded. Its main object was to secure the shaft walls pending the installation of the tubbing.

Up to the middle of July drilling was continued alternately with the large and the small trepans. At that time the latter had reached 197 meters (647 ft.), the former 181 meters (593 ft.) in depth. In this meantime, caving from the walls of the shaft became so serious that danger to the permanent masonry above 130 meters (427 ft.) was imminent. The large trepan had left a small shelf in a layer of gypsum at a depth of 163 meters (535 ft.), which was destined to be the support of the casing. On examination of the shaft, however, this shelf was found to have been washed away, and it became necessary to case the shaft immediately. As the plate. iron cylinder weighed 100,000 kilos (220,000 lbs.) and the rods available for lowering it were not sufficiently strong to carry this weight, the cylinder was cut in two. In order to furnish a support for it, the sump of the shaft was filled with gravel up to the 163-meter (535-ft.) point. The first section of casing was then lowered and hung from the collar of the shaft by six flat ropes, each 100 by 10 millimeters (4 by 0.4 inches) in cross-section, so that when the gravel was removed, these would support the casing. The ropes also acted as guides for the putting in place of the second section of casing, thus securing perfect alignment.

By the second week in September the casing had been put in place and spaces behind it filled with broken slag and stone. This was necessary as cavities had appeared in the walls of the shaft of sufficient size to cause displacement of the casing had any further

caving taken place. The broken stone and slag were deposited behind the casing by suspending a plate iron cone in such a way as to deflect the material into the annular space between the casing and the shaft walls. As there was some danger that part of the filling might slip out at the bottom of the casing, the lower outside edge was furnished with hinged flaps which would pass any obstacles on the way down, but were pressed down and outwards by the filling when deposited. Although this work was carried out with the greatest care, an inspection of the shaft showed that the casing had been squeezed out of shape to the extent of 160 or 180 millimeters (6.4 or 7.2 inches). This deformation was not serious, since the shaft was 4.95 meters (16.3 ft.) in the clear, and therefore large enough to permit the 4.1-meter (13.4-ft.) tubbing to be readily lowered and concreted.

On the 20th of September, the work of clearing the gravel out of the bottom of the shaft was begun, and on October 15 the original sump, which had been reached by the small trepan at a depth of 197 meters (645 ft.), was again cleared. Boring was then continued with the large trepan, now reduced to 4.92 meters (16.2 ft.) in diameter, as well as with the small trepan, 2.5 meters (8.2 ft.) in diameter. Work was stopped when the enlarging trepan had reached 204 meters (670 ft.) and the small one 215 meters (705 ft.). On January 18 preparations were made for lowering the tubbing, which was successfully completed March 4. Between that date and the 29th, the concreting was done, and on May 28, after the latter had set, pumping was started. The shaft proved to be completely water-tight, showing that the connection made in the rock salt was entirely satisfactory.

At present four shafts are being sunk by this method, one at Luebtheen, another near Hildesheim, and the others at Berka and Dietlas, the last two being in Thuringia.

The conditions prevailing at Berka are probably unique. At a depth of 130 to 145 meters (427 to 475 ft.), water was encountered under such pressure that 3 to 4 cubic meters (790 to 1,060 gals.) per minute are running out over the collar of the shaft. Drilling was commenced at a depth of 110 meters (361 ft.) and has been uninterrupted ever since. At present (end of July, 1901), the preliminary drilling has attained a depth of 166 meters (545 ft.) and it is expected that the waters will be permanently dammed back at 170 meters (557 ft.).

In conclusion, I will call attention to the problems now facing the mining industry in the sinking of very deep shafts in difficult ground, particularly with regard to character of the tubbing which will be necessary.

GENERAL CONCLUSIONS AS TO SHAFT DRILLING AND TUBBING AT GREAT DEPTHS.

Several shafts have recently been put down to depths of 600 meters (1,970 ft.), and it may reasonably be assumed that in future other such shafts will be undertaken which will require the use of the Kind-Chaudron method at very great depths. The formula for calculating the strength of the tubbing is $e = \left(\frac{R \times P}{s}\right)$.

Even for depths of say 400 meters (1,310 ft.), this calls for a very considerable thickness of the lower tubbing rings, on the basis of a working unit stress (s) of 800 kilos per square centimeter (11,350 lbs. per sq. in.). For instance, assuming R to be 2.2 meters (7.2 ft.) (outside radius of the tubbing), and $P = 40$ atmospheres, also e = thickness of metal, then $e = \frac{220 \times 40}{800} = 11$ centimeters (4.4 inches).

A thickness of 110 to 125 millimeters (4.4 to 5 inches) is, however, at present the outside limit which will permit the manufacturer to guarantee soundness of the castings. Aside from this, rings of such thickness are very difficult to transport on account of their great weight. It is not safe to exceed a working stress of 800 kilos per square centimeter (11,350 lbs. per sq. in.) for cast iron, and cast steel offers no advantages, as its coefficient of resistance is little if any greater. At great depths, therefore, it becomes necessary to diminish the diameter of the tubbing, if the lower rings are to be made of reasonable thickness. On the other hand, a material reduction in the diameter of the tubbing brings with it the disadvantage that the cross-section of the shaft would become too small to accommodate the necessary equipment, such as hoisting apparatus, pump columns, ladderways, etc.

General Manager Tomson at Gelsenkirchen has suggested, in the case of the two shafts near Werne, which were to be 580 meters (1,900 ft.) deep to the carboniferous ground, that if it became necessary to drill them, four sets of tubbing, two of 2½ meters (8.2 ft.) in diameter and two of 1.65 meters (5.4 ft.) in diameter,

should be put in place in the round shaft, 5.8 meters (19 ft.) as made by the drill. He further suggested that the space between the various sets of tubbing should be filled by concrete. The completed shaft would thus comprise four compartments. Each of the two larger tubbings would serve for hoisting purposes, the others being used for pumping and ladderways.

The thickness of tubbing of 2.5 meters (8.2 ft.) inside diameter for such an installation, would be 105 millimeters (4.2 inches) for a depth of 580 meters (1,900 ft.), and is consequently quite within the limits of good work on the part of the manufacturer. This system, which was patented under No. 99,867, was not used at Werne, however, as the Kind-Chaudron method was not required, the coal beds being reached by hand labor.

Instead of diminishing the diameter of the tubbing to such an extent that the thickness of metal will come within feasible limits, two concentric sets of tubbing may be used, provided that the annular space between the individual lines of tubbing be filled with concrete, or subjected to some sort of pressure, either compressed air or water under pressure. Assuming that the walls be calculated for a pressure of 30 atmospheres and that the space between them be filled with compressed air of that pressure, it is quite practicable to reach a depth of 600 meters (1,970 ft.). The outside cylinder would then be subject to a pressure of 30 atmospheres and the interior cylinder to a similar pressure from the outside, each being amply strong to resist this pressure.

Aside from the fact that by use of double tubbings the walls are reduced to a feasible thickness, we find in this arrangement a means of diminishing the difficulties in handling the tubbing, which frequently, in the case of very heavy castings, become almost insuperable. For example, in a shaft 600 meters (1,970 ft.) deep, the lower tubbing rings, respectively 4.1 meters (13.4 ft.) in the clear by 1.2 meters (3.9 ft.) high, would require a thickness of 180 millimeters (7.2 inches) and consequently would weigh 30,000 kilos (66,000 lbs.) each. The weight of the moss-box for such a lining would be approximately 70,000 kilos (154,000 lbs.).

For lowering the tubbing, the following method is in use. A platform is built above the water level in the shaft and on this the moss-box is set up. Upon the latter the first tubbing ring is put in place. The lowering apparatus is then attached; the ring and the moss-box are raised and the platform removed, allowing the

rings to be lowered into the water so that the upper edge of the tubbing still protrudes, say half a meter. In this position the moss-box and the tubbing will displace about 28,000 kilos (61,600 lbs.) of water, so that the lowering apparatus supports (70,000 + 30,000) — 28,000 = 72,000 kilos (158,400 lbs.). Each similar tubbing ring, 4.1 meters (13.4 ft.) in diameter and 1.2 meters (3 9 ft.) high, will displace 18,000 kilos (39,600 lbs.) of water. As the ring itself weighs 30,000 kilos (66,000 lbs.) each successive ring of the same thickness adds a further load of 12,000 kilos (26,400 lbs.). However, allowing for the decreasing thickness of tubbing toward the top, each ring added will weight the lowering appliances less than the previous one. Nevertheless, it is clear that the total weight of such a set of tubbing will soon become so large that it cannot be supported by any reasonably strong apparatus.

In the case of double tubbings, the individual rings have only half the thickness and half the weight. The first operation consists in lowering the moss-box with its accompanying ring. As the amount of water displaced per ring is 18,000 kilos (39,600 lbs.) and the weight of the ring only 15,000 kilos (33,000 lbs.) the weight on the lowering apparatus will be reduced by 3,000 kilos (6,600 lbs.) per ring. This reduction will increase with the decreasing thickness of the walls. Having inserted the usual diaphragm, a point is soon reached at which the lowering apparatus is entirely relieved of strain, and the tubbings, by virtue of their buoyancy will exert an upward pressure.

If the shaft be very deep, the possibility arises that the surplus buoyancy in the upper thin part of the tubbing, which was formerly counteracted by water ballast, will carry the weight of the interior tubbing. At this point work should commence with the installation of the inner tubbing rings at the bottom of the outside ones, which should keep pace with the erection of the outer tubbing. When the inner tubbing has reached the necessary height, the space between the two sets is closed above and filled with compressed air corresponding in its tension to the outside strain on the exterior tubbing. After closing the outside set of tubbing with the diaphragm, the whole can be lowered without danger.

When the lining comes to rest in the bottom of the shaft, the air is replaced by water, and the space between the walls of the shaft and the outside tubbing is concreted. If concreting is not resorted

LIST OF SHAFTS S

No.	Country.	Place.	
1	Germany	Rotthausen	Bergwerks-Ges. D
2	Belgium	Peronnes	Cie. des Mines de
3	"	"	" "
4	"	"	" " m.
5	Lorraine	Spittel	Saar und Mosel-B
6	"	"	" "
7	Germany	Rotthausen	Bergwerks-Ges. D
8	"	"	" by hand. They
9	France	Dorignies	Cie. des Mines de eventually aban-
10	"	"	" " " "
11	Belgium	Maurage	Cie. des Mines de
12	"	"	" "
13	"	Peronnes	" "
14	France	Liévin	" "
15	"	Meurchin	" " to a depth of 32 m.
16	"	Douchy	" " of 20 m.
17	Germany	Rotthausen	Bergwerks-Ges. D
18	France	Liévin	Cie. des Mines de
19	"	Meurchin	" "
20	"	Annezin	" "
21	"	Auchel	" " in depth.
22	Belgium	Giply	" " du
23	Germany	Rotthausen	Bergwerks-Ges. D
24	"	Spittel	Saar und Mosel-B
25	"	"	" "
26	Belgium	Giply	Cie. des Mines du
27	"	Ghlin	" " du of 285 and 320 m.
28	"	"	" " of 285 and 320 m.
29	France	Liévin	" " de

to, the water in the annular space between the two cylinders must be sufficiently high, on completion of the lining, to counteract the outside pressure on the exterior tubbing. Naturally, a set of tubbing will be very long in deep shafts and frequently exceed what is absolutely necessary for rendering the shaft water-tight. In such cases it is best to concrete the outside cylinder only, so far as it is required, and to remove the superfluous tubbing rings.

Where the conditions in a very deep shaft demand only a short length of double tubbing, the following system of lowering may be adopted. The outside cylinder, provided with upper and lower diaphragms, is lowered first in the usual manner. While it is sinking, compressed air is admitted through a pipe attached to the lowering rods. As the tubbing sinks deeper, the air pressure would be correspondingly increased, but should never exceed more than one half of the outside pressure at any one time. When the cylinder reaches the bottom, the air should be replaced with water and the outside cylinder as usual concreted. The upper diaphragm and equilibrium pipe are then taken out. Next, the lower diaphragm is either removed and the interior cylinder put in place with bottom and top in a similar manner, or else the lower diaphragm of the outer cylinder is allowed to remain for the time being, and the interior cylinder is lowered upon it. It is evident that the method of installing the tubbing will depend largely on the depth and will require careful consideration in each special case. A patent has been applied for covering the use of double tubbings and the application of compressed air or water under hydraulic pressure during the operation of lowering them.

The subjoined list of shafts already completed by means of the Kind-Chaudron system is very significant, in that it demonstrates that the method may be applied with assured success in spite of the greatest technical difficulties. A further circumstance is worthy of mention, viz: That the system has scarcely ever been applied except as a last resort, and that in such cases, it has been used only for comparatively small portions of the respective shafts; a fact which neutralizes in great measure the objection often raised that it is slow and very expensive. It may be added, moreover, that a system which thus far has invariably led to success even under the most difficult conditions, cannot be directly compared to other systems which have failed before it was brought into service. A parallel would be found in a comparison of two shafts

which were put down by hand, that one being wet, the other having to contend with an inflow of say 10 cubic meters (2,640 gals.) of water per minute. Frequently, it would be advisable to begin drilling operations before encountering the difficulties which make all other methods of sinking impossible. This is specially true when it is known beforehand that the system will ultimately have to be resorted to. Work might then commence under more favorable conditions, and being prosecuted with greater speed, would show a lower average cost, as well as permit of prorating the expensive preliminary expenditure over a greater length of shaft. Such a policy would avoid the very large expense which is usually incurred before insuperable difficulties force the abandoment of all other methods. The greater depth of shaft drilled could be completed more rapidly and cheaply than by other means, which latter would naturally involve the great expense incurred in sinking the last few meters by hand before stopping work. Operating costs for the ordinary methods of shaft sinking where large quantities of water have to be handled, are excessive and the progress is slow. Against this may be placed the fact that the running expenses of a Kind-Chaudron boring plant when actually at work are really very moderate.

A RAPID METHOD FOR THE DETERMINATION OF ARSENIC IN ARSENOPYRITE.

By J. L. DANZIGER AND W. H. BUCKHOUT.

[Contribution from the Havemeyer Laboratories, Columbia University, No. 80.]

The lack of a rapid method for the estimation of arsenic in arsenopyrite led to a series of experiments the results of which are given briefly in this article.

The favorite method for the determination of arsenic by smelter chemists has been that devised by Dr. Pearce and later modified by Canby and by Bennet; and while this is satisfactory for the majority of western ores containing small percentages of arsenic, it gives low results with arsenopyrite unless extraordinary precautions are taken to avoid volatilization of arsenic during the fusion. This difficulty can be avoided by using sodium peroxide in place of the mixture of potassium nitrate and sodium carbonate recommended by Pearce. The details are as follows: About half a

gram of the finely ground ore is mixed thoroughly with 10–15 grams of sodium peroxide in a wrought-iron or nickel crucible, and the mixture covered with a layer of the flux. It is heated to fusion and fused for five minutes, then leached with boiling water, boiled till the excess of peroxide is completely decomposed, filtered, and the filtrate treated exactly as described in Bennet's modification of Pearce's method.*

After this method of decomposition was tested, attempts were made to substitute a shorter method for the determination of the arsenic. There seemed two possible ways: 1st, an acidimetric method. 2d, by sodium thiosulphate.

Acidimetric Method.—If the alkaline solution containing sodium arsenate, sulphate carbonate, etc., is made acid with hydrochloric acid and the CO_2 expelled and then titrated back with standard alkali using methyl orange as an indicator, the change to yellow is produced when the excess of hydrochloric acid and one hydrogen of the arsenic acid are neutralized. If then phenol phthalein is added and the titration continued to pink, the additional alkali will be that required to change NaH_2AsO_4 to Na_2HAsO_4 or for one H one Na which is equivalent to one arsenic.

This method was tried with other indicators, phenol phthalein and congo red, luteol and dimethylamido ozo benzene being used, and while it may be useful when rapidity is more essential than great accuracy, the end points are not sufficiently sharp for it to be recommended.

Thiosulphate Method. — This is essentially the method proposed by Williamson and described by Sutton and is based on the liberation of iodine by arsenic acid and the estimation of the iodine by a standard solution of sodium thiosulphate. In order to get a quantitative liberation of iodine the solution must be very strongly acid and as this disturbs the blue color with starch, giving various pink shades, much difficulty was experienced with the end point. It was finally overcome by titrating without starch till only a trace of free iodine remained and then applying drops to spots of starch solution on a porcelain tile until no blue color was produced. In this way the hydrolysis of the starch was avoided and the titration is not tiresome, for it is not necessary to try the spot test till a few drops from the end, as this point is indicated by the fading of the yellow color due to the iodine. This titration combined with the

J. American Chem. Soc., Vol. 21, p. 431.

peroxide fusion was found to combine both accuracy and rapidity. In the absence of antimony it is carried out as follows:*

Half a gram of the finely ground ore is mixed in an iron crucible with 10–15 grams of sodium peroxide, and covered with a layer of sodium peroxide. Heat is applied very gently until the mass has sintered together and the upper layer of peroxide becomes deep yellow. Then the heat is increased to bright redness so that the mass melts down and becomes perfectly liquid. This heat is maintained for about five minutes and complete decomposition ensured by holding the crucible over the flame and causing the contents to rotate. A Bunsen burner will give all the heat required, as the decomposition is easily effected without the aid of a blast lamp. The manipulation is entirely similar to the well-known method for chromium in chromite.†

When the fusion is complete, it is allowed to cool and the melt leached with about 100 c.c. of boiling water, then boiled for a minute to decompose the peroxide, allowed to cool and transferred to a 200 c.c. graduated flask, diluted to the mark, mixed thoroughly, allowed to settle and then decanted through a dry filter; 100 c.c. of the clear filtrate is measured off by a pipette or flask and used for the determination of arsenic in order to save the time and the dilution involved in washing the precipitate of ferric oxide, etc. This filtrate is acidified strongly with concentrated hydrochloric acid and concentrated to about 75 c.c., so that all the carbonic acid is expelled. No reduction of arsenic acid has been observed at this point as the concentration of hydrochloric acid is small. Next 75 c.c. of conc. hydrochloric acid (1.2 sp. gr.) are added and the solution allowed to cool to the room temperature, then three grams of potassium iodide are added, best as a saturated aqueous solution, and the liberated iodine is titrated immediately with a standard sodium thiosulphate solution (approximately $N/10$) until the color of the solution is very light yellow, then drops of starch solution are placed on a white tile and the titration continued until a drop gives no blue color.

If the thiosulphate solution has been standardized by copper, iodine or potassium dichromate the calculated value in terms of arsenic will not agree exactly, under these conditions of titration,

* "Volumetric Analysis," p. 65, 8th Edition. Compare also Meade, *J. Am. C. S.*, 21, 750.

† Waller, *J. S. C. I.*, Vol. 15, p. 436.

with those found by titration against arsenic. The variation is however almost constant and if one per cent. of the standard in terms of arsenic is added to the calculated value the results will be very close to the truth. This discrepancy of one per cent. has already been observed with antimony in Youtz' * conditions for the Herroun-Weller method, so when these conditions for titration are strictly maintained the arsenic standard can be calculated from the antimony standard or vice versa. It is however safer to standardize by arsenic. Weigh out several portions of resublimed arsenious oxide (As_4O_6); place them in small beakers, add to each .5 gram of potassium chlorate then 20 c.c., of concentrated hydrochloric acid and heat till all chlorine is expelled and the solution is colorless; dilute to 75 c.c., add 75 c.c. of conc. hydrochloric acid, allow to cool, and carry out the titration as already described. The following precautions must be observed:

1. Before the fusion, the first heating must be done very cautiously, to avoid loss of arsenic. This is done by using a small flame which is kept in motion so that it heats different portions of the crucible in turn.

2. The solution obtained by leaching the melt must be boiled vigorously to decompose the excess of sodium peroxide and manganates.

3. The solution before the addition of potassium iodide must be at the room temperature (*i. e.*, about 20° C.) and must be titrated immediately. The question of temperature is of great importance in this titration.

4. Not more than four grams of potassium iodide should be used.

5. The acidity should be the same each time 20 per cent. actual HCl (⅓ vol. of conc. HCl) is recommended. If the solution is not sufficiently acid, the liberation of iodine is slow and the titration becomes tedious. More hydrochloric acid, on the other hand, causes precipitation of too much NaCl. Uniformity in the conditions for titration is essential, not only in respect to the amount of potassium iodide added and the temperature, but also as regards the time which elapses after the potassium iodide is added as well as the acidity.

Of the elements which would interfere in this method antimony is the only one likely to be found associated with arsenic in ores. Its removal is conveniently effected by Bunsen's separation, as follows: To the filtrate from the fusion, hydrochloric acid is added

* Dissertation Columbia University, 1902.

until the solution is just distinctly acid: then cooled to the room temperature and a rapid stream of sulphuretted hydrogen is passed in till the antimony is completely precipitated as antimony pentasulphide. As soon as the precipitation is complete the sulphuretted hydrogen is expelled by a current of air (not by heat) and the sulphide filtered and washed with cold water.

When a considerable quantity of arsenic is present this method has been found to give antimony pentasulphide entirely free from arsenic. The filtrate containing the arsenic is oxidized by potassium chlorate and hydrochloric acid boiled to expel chlorine, etc., brought to the standard conditions and titrated.

A comparison of results on three ores is as follows:

	No. 1.	No. 2.	No. 3.
Gravimetric weighing as $Mg_2As_2O_7$	37.33	16.27	10.26
Volumetric, Pearce (Bennet)	37.57		
Volumetric, Pearce (Na_2O_2 fusion)	38.09	16.66	10.41
New method	37.88	16.60	10.40
	37.95	16.68	
	38.10		

The results are higher in all cases; this we believe to be due to the more perfect oxidation, effected by the sodium peroxide. This method of decomposition, by fusion with sodium peroxide, was also tried on Franklinite ores for the separation of zinc from manganese and iron and proved to give complete decomposition and accurate results which agreed with the regular gravimetric methods.

QUANTITATIVE LABORATORY, April, 1903.

BOOK REVIEWS.

Lead Smelting: The Construction, Equipment and Operation of Lead Blast Furnaces, and Observations on the Influence of Metallic Elements on Slags, and the Scientific Handling of Smoke. By MALVERN WELLS ILES, Ph.D. New York, John Wiley & Sons. 1902. Pp. 211.

In explaining the scope and purpose of his book Dr. Iles says:

"The chasm separating theoretical from practical results is sufficiently wide and deep to engulf unmeasured capital and vaultless ambition. The theory of smelting is a prerequisite to successful practice, but its mastery does not complete the equipment. Experience in applying the principles of chemistry and metallurgy to the hard problems of smelting activity, under widely varying conditions and environment, is a no less important factor in achieving financial as well as theoretical triumphs over nature. My initial endeavors were almost coincident with the birth of the industry of lead smelting in the United States. * * * The knowledge acquired during a period covering two decades came through direct contact with the sterner realities of smelting life, and by means of tests and experiments incident to the handling of a wide range of mineral substances, by all the manifold processes and devices discovered from time to time. * * * To the younger men of the period, on whose shoulders rests the responsibility for maintaining steady progress in the science of metallurgy, I cheerfully dedicate this volume, in the confident hope that it may be serviceable in the solution of problems along the broader lines, and useful as well in many of the lesser details."

Add to this that, in the profession for which this book is written, no man stands higher in the opinion of the practical men than Dr. Iles, and the value of this little book is defined.

The first 140 pages are devoted to the blast furnace, its design, operation and products. The contingencies most likely to be met with in practice, from the time of blowing in until the campaign is ended, are successively brought up and the best way to handle them pointed out. A too brief reference to roasting furnaces follows, and then the remaining third of the book is given up to the subject of smoke. On page 175 the writer says:

"The chief metallurgical losses that occur in treating gold, silver and lead ores are loss through smoke and slag. * * * The losses through the slag are now virtually overcome by the use of slag settlers. The saving of those passing off in the fume of roasting furnaces is yet to be achieved. * * * The successful installation of the bag-house, for collecting fumes from furnaces smelting lead, gold and silver ores, marks the greatest step taken in [non-ferrous] metallurgy during the century."

On this point Dr. Iles has recorded a number of experiments made by himself, in such plain language that the beginner in the study of the subject or the least educated of furnace foremen can readily understand.

BRADLEY STOUGHTON.

The Hydro-Metallurgy of Copper: An account of Processes Adopted in the Hydro-Metallurgical Treatment of Cupriferous Ores, Including the Manufacture of Copper Vitriol with Chapters on the Sources of Supply of Copper and the Roasting of Copper Ores. By M. EISSLER, M.E. D. Van Nostrand Co., New York; Crosby Lockwood & Son, London, 1902. Price $4.50 net.

The subject of the lixiviation of copper ores is one which has considerable interest to metallurgists, and comparatively little is known about the more modern methods used, which are more or less localized and kept secret. That the author has found difficulty in getting data, is apparent from his remark that: "It will be readily understood that, for various commercial reasons, access for purposes of investigation, to the various establishments, where such processes are carried on, is denied — a fact which accounts for the lack of detailed information on the subject."

Although the title would seem to imply that the book was almost entirely devoted to the lixiviation of copper, such is not at all the case. The work as a whole is divided into three parts, and only one of these, comprising about sixty of the two hundred odd pages is devoted to the lixiviation processes. The other two parts treat of the distribution and occurrence of copper ores, and the roasting of such ores, respectively.

The first part of the book comprises four chapters and in these the author treats of the chemical properties of copper in considerable detail, and then takes up a discussion of a great number of copper mines scattered all over the world, and here he also considers the manner of occurrence of the ore in each particular region.

In this connection there are many statistics given with reference to the various mines, and he concludes with a detailed account of the Huelva district of Spain, where the famous Rio Tinto mines are located.

Part II. is devoted to a discussion of the various leaching processes now used in different places, and especially the work done at the Rio Tinto district.

The refining of the cement copper obtained is set forth briefly, and this section concludes with a description of the manufacture of blue vitriol.

The third division of the book is given up to the roasting of copper ores. Here, the various methods of roasting in heaps, kilns and mechanical furnaces, are discussed, and in this connection there are numerous drawings of the various furnaces used. The book concludes with a brief illustrated chapter devoted to the consideration of gas producers.

H. W. GEROMANOS.

JUST PUBLISHED

8vo, Cloth, 287 Pages, Illustrated. Price, $3.50 *net*
Postage 25 cents

Conductors for Electrical Distribution;

Their Materials, and Manufacture, the Calculation of Circuits, Pole Line Construction, Underground Work, and Other Uses

By F. A. C. PERRINE, A.M., D.Sc.

Formerly Professor of Electrical Engineering, Leland Stanford, Jr., University; Member American Institute Electrical Engineers

---

8vo, Cloth, Illustrated, 122 pp. Price, $1.25 *net*
Postage 10 cents

Experiments on the Flexure of Beams

Resulting in the Discovery of New Laws of Failure by Buckling

By ALBERT E. GUY

Reprinted from the "AMERICAN MACHINIST"

8vo, Cloth, 1100 Illustrations, 460 pp. Price, $3.00

THIRD ENGLISH EDITION REVISED

Handbook on the Steam Engine

With Especial Reference to Small and Medium-Sized Engines

For the Use of Engine Makers, Mechanical Draughtsmen, Engineering Students, and Users of Steam Power

By HERMAN HAEDER, C.E.

Duisburg-on-the-Rhine

Translated from the German, with Considerable Additions and Alterations

By H. H. P. POWLES

Assoc. Memb. Inst. C.E., M.I.M.E.

D. VAN NOSTRAND COMPANY

Publishers and Booksellers

23 MURRAY and 27 WARREN STS., NEW YORK

Copies Sent Prepaid on Receipt of Price

Woodbridge School,

FORMERLY

School of Mines Preparatory School.

---

417 Madison Avenue,

Between 48th and 49th Streets, NEW YORK CITY

Twenty-second Year Begins October 1st, 1903.

THE school is well equipped with physical and chemical laboratories, in which the students are required to perform a complete set of experiments illustrative of their recitations in physics and general chemistry. A special laboratory is devoted to qualitative chemical analysis for advanced students.

Five hundred Students of Columbia School of Mines have been instructed in the Woodbridge School. Also a large number have been prepared for Massachusetts Institute of Technology, Stevens Institute, Sheffield Scientific School, Lawrence Scientific School, Troy Polytechnic Institute, Cornell University, and the Classical, Medical, and Law Departments of Harvard, Yale, Columbia and Princeton.

A summer school for students who have failed in June begins August 13th and coaches men for the Fall examinations. All classes are limited to five. College men are coached in Freshman and Sophomore Mathematics and Quantitative Analysis.

An advanced course for older students prepares them to enter the second year class. Last June one of our students received his degree in Electrical Engineering in three years.

VOL. XXIV. No. 4. JULY, 1903.

THE SCHOOL OF MINES QUARTERLY.

A

JOURNAL OF APPLIED SCIENCE.

BOARD OF EDITORS.

A. J. MOSES, Prof. of Mineralogy.
J. F. KEMP, Prof. of Geology.
R. PEELE, Adj. Prof. of Mining.
A. D. F. HAMLIN, Adj. Prof. of Architecture.
R. E. MAYER, Instructor in Drawing.
E. WALLER, Analytical Chemist.
JOS. STRUTHERS, Ph.D.,
I. H. WOOLSON, Instructor in Mechanical Engineering.
W. H. FREEDMAN, E.E.,
T. H. HARRINGTON, Tutor in Drawing

Managing Editor, R. E. MAYER,
Business Manager, T. H. HARRINGTON.

CONTENTS:

A Study of the Quantitative Determination of Antimony. By Lewis A. Youtz 407
The Rossie Lead Veins. By C. H. Smyth, Jr. 421
Laboratory Notes for Students in Practical Electrochemistry. By S. A. Tucker 429
On the Use of Influence Lines in Graphic Statics.—Part III. By Myron S. Falk 440
The Geology of the Cerrillos Hills, New Mexico. By Douglas Wilson Johnson 456
The Production of Anisic Acid by the Oxidation of Aniseed Oil. By Marston Taylor Bogert and Carl H. Zieme 500
Abstracts—Analytical Chemistry. By Elwyn Waller 510
Book Reviews 514

COLUMBIA UNIVERSITY
NEW YORK CITY.

Registered at the New York Post Office as Second Class Matter.

TWO DOLLARS PER YEAR. FIFTY CENTS PER NUMBER.
All Remittances should be made payable to Order of "The School of Mines Quarterly."

Portland Cement

THE LAWRENCE CEMENT CO.

ESTABLISHED 1832.

ERNEST R. ACKERMAN, President

This Company has manufactured and sold during 70 years upwards of **20,000,000** barrels of Cement; marketing the product in all the principal cities of the United States, Canada, West Indies, Philippines and South America.

The old Custom House on Wall Street, built in 1835–37, and the new Custom House on Bowling Green, now under construction, were built with cement sold by this Company.

Used on the Old and on the New Stock Exchange in New York City, on the Brooklyn Bridge and New East River Bridge, and on the new Chamber of Commerce Building.

Detailed list of important Government Work Reservoir Dams, Sidewalks, Fortifications, Bridges, Municipal Buildings and Railroad Work where "DRAGON" has been used, furnished on application.

DRAGON PORTLAND CEMENT Stands the Highest Requirements of Architects, Engineers and Builders.

SALES OFFICES:

NEW YORK, No. 1 Broadway. 15th and Market Sts., PHILA.

JENKINS '96 PACKING

Has every quality for making a perfect joint under any and all conditions that sheet packing is used. It makes joint immediately.

It is not loaded to increase weight—weighs less per square yard than many other packings, therefore the cheapest and best joint packing for users now on the market.

ALL GENUINE—stamped with Trade Mark as shown in the cut—is fully guaranteed.

JENKINS BROS., New York, Boston, Philadelphia, Chicago

THE

SCHOOL OF MINES QUARTERLY.

VOL. XXIV. JULY, 1903. No. 4.

[Contribution from the Havemeyer Laboratories of Columbia University, No. 63.]

A STUDY OF THE QUANTITATIVE DETERMINATION OF ANTIMONY.

BY LEWIS A. YOUTZ.

PART II.

AN INVESTIGATION OF THE HERROUN*-WELLER'S† VOLUMETRIC METHOD FOR THE DETERMINATION OF ANTIMONY.

The various methods proposed for the volumetric determination of antimony depend either upon the direct oxidation or reduction of the antimony by the titrating solution; or indirectly upon the titration by means of sodium thiosulphate of the iodine liberated in the reduction (KI and HCl ‡), or in the oxidation (the iodic acid method §); or the titration of a product reduced by the antimony compound (as $FeSO_4$ by $KMnO_4$, etc.).

Evidently a method depending upon the reduction of the antimony compound in the titration could be quantitatively accurate only if the highest state of oxidation had been completely reached for the antimony preceding the titration; or conversely an oxidation titration could be accurate only after a reduction of the antimony to some known degree.

The discordant results in determining antimony volumetrically obtained by some investigators in comparing different methods

* *Chem. News*, 45, 101, 1882.

† *Ann.*, pp. 362–369, 1882.

‡ *Ibidem.*

§ Causse, *Compt. Rend.*, 125, 1100, 1897.

doubtless were in part due to incomplete oxidation or reduction. It was noted further that O. Bosek* in experimenting on the action of potassium chlorate and nitric acid in oxidizing antimony compounds, found that antimony could not be completely oxidized by either of these reagents. The best oxidation he could get by means of $KClO_3$ was 87.65 per cent. of the antimony oxidized. By the use of fuming nitric acid he could get only 98.23 per cent. oxidized. By the use of bromine in alkaline solution his results were as follows:

	Unoxidized
4 hours boiling of the solution with bromide,	3.89%
10 " " " " " "	1.51%
12 " " " " " "	0.00%

With this work before us it became necessary to investigate carefully the completeness of the oxidation of the antimony when treated with potassium chlorate, nitric acid, or the other usual oxidizing materials.

1. Oxidation of Antimonious Compounds.

Metallic antimony as pure as possible (Kahlbaum's) was used as a basis for all the work done. Potassium chlorate, or nitric acid with concentrated hydrochloric acid were used throughout the work for dissolving the antimony.

As a basis for determining the degree of oxidation, potassium iodide in acid solution seemed to offer as convenient a reducing agent as any, and iodine in alkaline solution a satisfactory oxidizing agent. These were used as in the well-known method of Weller for the oxidized acid solution, and Mohr for the alkaline reduced solution.

Determination of Standard Sodium Thiosulphate and Standard Iodine.

First attention was directed toward the preparation of reliable standard solutions of sodium thiosulphate, and of iodine. The sodium thiosulphate solution was checked against potassium bichromate, electrolytic copper, and resublimed iodine. The iodine standard was then carefully checked against this sodium thiosulphate.

(*a*) *Standardization Against Bichromate of Potash.*—The following conditions were found to give good results.

* *Jour. Lon. Chem. Soc.*, 1895 (trans.), 515.

(1) Approximately .2000 g $K_2Cr_2O_7$, powdered and dried at 130° for 12 hours.

(2) 600 c.c. to 700 c.c. water.

(3) 3 grams of KI crystals added after acidifying.

(4) 15 c.c. of concentrated H_2SO_4.

(5) 1 c.c. starch solution, added near the end of the titration.

With the sulphuric acid as acidifying agent the iodine was set free readily and a sharp end point obtained.

(*b*) *Standardization Against Copper.*—.1000 to .1500 gram of pure copper foil was weighed out, dissolved in a small portion of nitric acid, evaporated very nearly to dryness on the water-bath (less than 1 c.c. of free acid), diluted to 10 or 20 c.c., made very slightly alkaline by dilute potassium hydrate, acidified by acetic acid, boiled for 2 or 3 minutes, cooled, diluted to 50 c.c. or 60 c.c., 2 or 3 grams of potassium iodide added, and titrated by sodium thiosulphate.

(*c*) *Standardization Against Iodine.*—A portion of iodine (Kahlbaum) was resublimed with potassium iodide, dried over calcium chloride, and portions of this weighed out between small watch glasses, the glasses with the iodine placed in potassium iodide solution, the iodine dissolved, and titrated. Portions from the bottle direct gave the same results. So the original sample was considered pure.

RESULTS BY THE THREE METHODS.

The average for each method when calculated to the antimony equivalent is as follows, the atomic weights being taken as: Cu, 63.6; K, 39.11; Cr, 52.1; O, 16; I, 126.85 and Sb, 120.4.

Bichromate titration	=	.0064927 Sb per c.c. hypo.
Iodine	"	.0064990 " " " "
Copper	"	.0064947 " " " " .

Testing the Oxidation and Conditions for Titration.

In making the solution of the antimony for each determination a weighed portion of the powdered sample was taken and dissolved in hydrochloric acid with a small quantity of nitric acid, or potassium chlorate, and generally both were used. The nitric acid however is by far the best solvent. No tartaric acid was used for fear of a possible interference in the titration. The excess of the chlorate or nitric acid were decomposed by the addition of an excess of hydrochloric acid and the solution boiled till the complete removal

of chlorine and of nitrogen oxides. After dilution a portion of potassium iodide was added and the liberated iodine titrated directly by the standard sodium thiosulphate that had been checked as before indicated.

If the portion of antimony had been completely oxidized to antimonic acid,* then on adding an excess of potassium iodide, iodine should be liberated equivalent to the antimony taken, providing, (1) that the hydriodic acid from the potassium iodide in acid solution had reduced the antimony completely to the trivalent form; (2) that the antimony contained no impurities; (3) that the hydrochloric acid, or dissolved oxygen had no decomposing effect on the hydriodic acid; and (4) that there had been no loss by volatilization, or otherwise, in getting the solution of the antimony.

The limits of hydrochloric acidification were carefully tested. It was found in adding three grams of potassium iodide to 400 c.c. of water acidified respectively with 10 c.c., 20 c.c., or 30 c.c. of concentrated hydrochloric acid, only a faint blue color was imparted to starch added as an indicator after standing ten minutes in the case where 30 c.c. of acid had been added. About 20 c.c. of acid to 400 c.c. of water was thus the limit for safe titration. Otherwise iodine would be liberated by the acid alone. Of course, hydrochloric acid of itself does not decompose hydriodic acid, but the dissolved oxygen of the solution causes the liberation. This was verified by adding potassium iodide to acidified water which had been boiled to remove dissolved oxygen and then allowed to stand in an atmosphere of carbon dioxide. Only traces of iodine were liberated on standing for several hours.

Experiments were also made to determine the limits as to the amount of potassium iodide to be used as well as the acidification of the antimony solution. The conditions best suited for the titration were found to be as follows:

To .2000 gram of antimony (metallic) dissolved and oxidized by nitric acid and hydrochloric acid, or potassium chlorate and hydrochloric acid. The solution is then concentrated to about 50 c.c. This solution would be about 20 per cent. hydrochloric acid. To this must be added about 15 c.c. to 20 c.c. of concentrated hydrochloric acid, and the whole diluted to 600 c.c. or 700 c.c. Three grams of crystals of potassium iodide are then added, the liberated iodine titrated nearly to the end, 1 c.c. of starch solution intro-

* See Part I., this Journal, June, 1903, No. 2.

duced and the titration completed, *i. e.*, to no blue color. The end point is very sharp.

If a much smaller amount of potassium iodide is added the liberation of iodine is slow and a definite end point is reached which showed incomplete reduction of the antimony. Further, if a much smaller amount of hydrochloric acid be used, a precipitate from white to red is formed during the course of the titration. This precipitate was proved to vary from antimony oxychloride (SbOCl) to antimony oxyiodide (SbOI).

The results of a large number of titrations under the above conditions were found to be as follows:

Sb taken.	Sb found.	Per cent. of Error.
.1781 g.	.1766	.85 % low.
.1883 "	.1868	.84 " "
.2119 "	.2098	.99 " "
.2224 "	.2202	.99 " "
.2306 "	.2289	.73 " "
.2055 "	.2033	1.05 " "
.1358 "	.1341	1.25 " "
.1505 "	.1487	1.19 " "
.1547 "	.1535	.77 " "
.1451 "	.1432	1.50 " "
.1400 "	.1387	.92 " "
.1587 "	.1565	1.32 " "
.1557 "	.1539	1.16 " "
.1962 "	.1938	1.22 " "
.2508 "	.2480	.88 " "
.2626 "	.2602	.90 " "
.2179 "	.2161	.85 " "
.2284 "	.2261	.99 " "
.1941 "	.1918	1.18 " "
.2476 "	.2452	.96 " "
.2095 "	.2068	1.29 " "
.1975 "	.1951	1.21 " "
.1900 "	.1893	.37 " "
.2065 "	.2048	.82 " "
.1893 "	.1873	1.08 " "
.2220 "	.2198	.96 " "

These experiments showed an error of 1 per cent. on an average, which at first was thought to indicate incomplete oxidation. To show, however, that this was not the case, a number of experiments were performed, where weighed portions of antimony were dissolved and oxidized as in the above determinations, tartaric acid added, neutralized nearly by sodium carbonate, and rendered alkaline by

an excess of sodium bicarbonate as is usual in Mohr's titration method. The alkaline solution was then titrated by standard iodine. Blanks were also run where about the same amount of hydrochloric acid was taken as in making the antimony solution, this boiled with 1 c.c. concentrated nitric acid and small portions of potassium chlorate, the chlorine boiled out, tartaric acid added, rendered alkaline, and titrated by iodine, results as follows:

Sb Taken.	c.c. Iodine used.	Sb indicated.	Per cent. Sb Equivalent.
.2765	0.30	.001326	0.45
.2515	0.20	.000884	0.35
.2093	0.15	.000633	0.30
.1663	0.20	.000884	0.50

The average of several blanks gave:

0.15 iodine = .000633 Sb.

On the supposition that an antimonious salt in alkaline solution is completely oxidized on titration by iodine, the results of the above work would undoubtedly show that antimony is completely oxidized to the highest state by potassium chlorate and nitric acid in hydrochloric acid, or at least within the limits of experimental error. I was unable to understand the results of Bosek given on page 408.

2. Testing for Impurities in the Sample of Antimony Used.

The almost constant error of 1 per cent. low in the titrations of antimony therefore was not due to incomplete oxidation. A series of investigations were now made in the hope of discovering the cause of the error. Naturally it was thought to be due to an impurity in the antimony sample, so a number of tests were very carefully carried out to find the impurity if possible. The sample of antimony was "Kahlbaum's best," and it was hardly expected to be impure. The following materials were most carefully tested for: sodium, potassium, copper, bismuth, lead, silver, tin, iron, phosphorus, sulphur and oxygen. Among these only a trace of iron was found. This however would give high results in the titration, and not low, as was constantly found. Arsenic would also give high results if present. The oxygen was tested for by making a combustion of the sample in a stream of hydrogen. No impurities being found, attempts to make metallic antimony from recrystallized tartar emetic were made, so as to compare results of the titration on this sample.

First "c. p." tartar emetic recrystallized three times was heated in air, till a mass of metallic antimony and antimony oxide had formed, then this mass was fused with potassium cyanide. This sample was found to contain about 2 per cent. of impurity, potassium as one part. Next antimony was obtained by the direct fusion of the tartar emetic. Two samples made by this method, on titration by the same method as above, gave .92 per cent. low and .74 per cent. low respectively. Potassium was tested for in these samples and none found. Still another sample of antimony was made by producing antimony hydride by zinc and acid in the ordinary Marsh apparatus, this decomposed in a tube at red heat, and the metallic antimony deposited, then titrated. The usual 1 per cent. low resulted in this sample as in the others.

From the tests it seemed impossible that the error was due to an impurity.

3. Testing for Volatilization or Mechanical Loss.

The vessel used in making the solution of the antimony in most of the above experiments was a beaker of about 800 c.c. capacity, covered with a watch glass. Thinking that there might be mechanical loss in boiling, several samples were dissolved and oxidized, using instead of the beaker a long-necked Kjehldahl flask. The solution was then titrated. The usual 1 per cent. low was found.

To more carefully test the volatility of the antimony in going into solution, samples were dissolved in the above flask, connected with a condenser and all products distilling over collected in a vessel of water, the delivery tube dipping into the liquid. To this water and distillate was added a few cubic centimeters of sulphuric acid, evaporation made on a water-bath, till most of the water, hydrochloric and nitric acid had evaporated. The residue gave no test for antimony. Two samples of antimony from which the distillate had been thus collected and tested gave when titrated 1.06 per cent. low, and 1.20 per cent. low respectively. The low results evidently were not due to volatilization, which again confirms the results obtained in testing the non-volatility of antimonic acid recorded in Part I. of this paper.*

Determination of Antimony Electrolytically.

To test still further whether the sample weighed out in each

* This Journal, January, 1903.

titration contained actually as many milligrams of antimony as the weight indicated, a number of samples were weighed, dissolved and oxidized as usual, titrated without starch as indicated, the antimony then precipitated by sulphuretted hydrogen, this sulphide dissolved by sodium sulphide and electrolyzed.

Conditions of the electrolysis were as follows:

(1) 50 c.c. of a saturated solution of sodium sulphide.

(2) 30 c.c. of water.

(3) 60 c.c. to 70 c.c. of a 20 per cent. solution of sodium sulphite.

(4) This mixture with the antimony warmed till colorless in a platinum dish.

(5) One series was electrolyzed at 60° C. for three or four hours with a current of 0.7 to 1.00 ampère. The other series electrolyzed at the ordinary temperature with current of 0.25 ampère over night.

Results of series electrolyzed at 60° C.:

Sb taken.	Sb Found by Titr.	Per Cent. Error by Titr.	Sb Found by Elect.	Error by Elect.
.2140	.2119	.90 low.	.2166	1.2 % high.
.2316	.2292	1.00 "	.2318	0.0 " "
.2825	.2795	1.03 "	.2844	.67 " "

Electrolyzed at ordinary temperature:

Sb Taken.	Sb Found.	Per Cent. Error.
.2258	.2262	0.00
.2743	.2747	0.00
.2136	.2150	.65 % high.
.2227	.2243	.75 " "

It was very difficult to get good results by electrolyzing under these conditions, and these seem to be the most favorable yet known. The results were not concordant, though if they show anything, it is that the antimony was present as weighed out. The deposit in all these cases was well adherent and of dull metallic luster. There is a great tendency to deposit sulphur, however, and the method seemed to be unreliable as a check.

4. Reduction of Antimony to the Trivalent Form.

Historical.

The work so far gives no explanation of the one per cent. error. It could yet be due to at least one other cause, viz., incomplete reduction by the hydriodic acid. Indeed complete reduction of antimony has been found to be difficult especially when boiled with

sulphur dioxide, or sodium sulphite in acid solution, as is most usual in getting the antimony in condition for Mohr's titration.

Knorre * states that good reduction of antimony by sodium sulphite in acid solution is not possible in an open vessel, but by adding a small amount of sodium sulphite to the acid solution in a bottle, then closing the bottle and heating on a water-bath, thus allowing the sulphur dioxide to act under considerable pressure, the reduction is complete.

Clark † found that antimony ores, if dissolved by hydrochloric acid in the presence of iodine, are oxidized only to the trivalent form, and if after boiling out the excess of iodine, or titrating the lost traces of iodine by sodium sulphite, the solution is neutralized and titrated by iodine, good results could be obtained.

Gooch and Gruener ‡ reduced the solution by boiling it with potassium iodide in acid solution, taking up the last traces of iodine with sulphur dioxide. They considered the reduction complete.

M. Rohmer § says antimony cannot be completely reduced by boiling with sulphur dioxide alone, but if one gram of potassium bromide is added with the sulphur dioxide, the reduction is complete.

Experimental.

Testing Methods of Reduction.

(*a*) *Sulphur Dioxide in Open Vessel.* — In these experiments the metallic antimony was dissolved in hydrochloric acid, nitric acid and potassium chlorate as usual in a tall beaker covered with a watch glass. After boiling out the free chlorine, 30 c.c. of an approximately 5-per-cent. sulphur dioxide solution were added, most of the free sulphur dioxide removed by boiling, then 30 c.c. more of the sulphur dioxide added, and boiled out completely. Two grams of tartaric acid were then added, the solution made alkaline by sodium bicarbonate and titrated by standard iodine. The iodine standard had been carefully checked against the sodium thiosulphate solution used in all the previous titrations.

Results as follows:

---

* *Zeits. Angew. Chem.*, 155–157, 1888.

† *J. S. C. I.*, 1896, 255–257.

‡ *Am. Jour. Sci.*, 3, 42, 213–220.

§ *Ber.*, 1901, 34, 1565.

Sb Taken.	Sb Found.	Per Cent. Error.
.2075	.2055	.96 low.
.1817	.1794	1.26 "
.1963	.1940	1.12 "

(*b*) *Sulphur Dioxide in Closed Vessel.* — Two experiments were made when the oxidized solution was placed in a strong bottle, 60 c.c. of the sulphur dioxide solution added, the bottle closed gas-tight and heated for an hour immersed half-way in a water-bath. The sulphur dioxide then boiled out, tartaric acid added, made alkaline and titrated by iodine. Results:

Sb Taken.	Sb Found.	Per Cent. Error.
.1706	.1684	1.20 low.
.2262	.2232	1.30 "

(*c*) *Precipitation as Sulphide and Solution in HCl.* — In this experiment the antimony was dissolved as usual and titrated by sodium thiosulphate, the antimony precipitated by hydrogen sulphide, this dissolved in concentrated hydrochloric acid, the hydrogen sulphide removed by warming (not boiling), tartaric acid added, etc., and titrated.

The reduction here depends on the fact generally recognized that antimony precipitated in the form of antimony pentasulphide is converted to antimony trichloride by solution in hydrochloric acid, sulphur being freed in equivalent amount.

Sb Taken.	Sb Found by Hypo.	Per Cent. Error.	Sb by Iodine.	Per Cent. Error
.2065	.2242	1.10 low.	.2048	.87 low.

(*d*) *Reduction by Sulphur Dioxide and Potassium Bromide.* — The solution was treated with 40 c.c. of the sulphur dioxide solution and 1 gram of potassium bromide, as suggested by Röhmer. The sulphur dioxide was then boiled out and the antimony titrated by iodine.

Sb Taken.	Sb Found.	Per Cent. Error.
.2495	.2465	1.2 low.

By these other methods of reduction it is seen that no higher results were obtained than had been secured by the sodium thiosulphate titration, and consequently if the low results were due to incomplete reduction, no better results could be obtained by these means than by potassium iodide in cold acid solution.

(*e*) *Reduction by Potassium Iodide in Acid Solution by Boiling.* A few experiments were made where two or three grams of potassium iodide were added to the oxidized solution and the liberated iodine distilled over, thus hoping to get better reduction by the

boiling hydriodic acid solution. The difficulty of driving the last portions of iodine over here were considerable, so that in each case the last portions of iodine in the solution had to be taken up with sulphur dioxide, or sodium thiosulphate before neutralization. This introduced a complication that made the method uncertain and concordant results difficult to obtain.

(*f*) *Effect of Largely Increasing the Potassium Iodide.* — It was thought that possibly better reduction (if indeed it was not already complete) would be obtained by adding larger amounts of potassium iodide before titrating with sodium thiosulphate. In these experiments the condition as to the amount of hydrochloric acid was the same as in all other sodium thiosulphate titrations. The results were as follows:

Sb Taken.	KI Added.	Sb Found.	Per Cent. Error.
.2205	1 gram.	.2176	1.32 low.
.2470	2 "	.2440	.91 "
.2230	2.5 "	.2208	.96 "
.2280	5 "	.2259	.91 "
.2459	5 "	.2436	.92 "
.2276	10 "	.2265	.48 "
.2111	10 "	.2094	.80 "
.2610	10 "	.2594	.59 "
.2152	20 "	.2142	.47 "
.2665	20 "	.2651	.51 "
.2214	20 "	.2208	.30 "
.2578	40 "	.2578	.00 "
.2273	40 "	.2275	.00 "
.2417	60 "	.2424	.38 high.

It was at first thought that possibly the iodine freed by adding the potassium iodide to the antimonic compound formed a balanced reaction with the antimony as in the equation

$$Sb_2O_3 + 2H_2O + 4I \rightleftharpoons 4HI + Sb_2O_5.$$

If such a balance should be established the amount of iodine thus made to reoxidize antimony would depend upon the concentration of the hyriodic acid in the solution. By increasing this concentration by the addition of a larger quantity of potassium iodide, it was hoped that finally a point would be reached where an amount of iodine would be freed exactly equivalent to the antimony. The results, as seen from the table, seemed to bear out this view till the last experiment was performed, when it was seen that too large an amount of iodine had been freed. Then a number of blanks were

run where in each case 700 c.c. of water was acidified with hydrochloric acid to the same degree as in the usual sodium thiosulphate titrations, and the amount of potassium iodide varied. The iodine liberated was taken up by sodium thiosulphate. The results were as follows:

H_2O	HCl	KI	Iodine After 10 Minutes' Standing.
700 c.c.	30 c.c.	3 grams.	0.00
700 "	30 "	10 "	.10 c.c. hypo.
700 "	30 "	20 "	.20 " "
700 "	30 "	40 "	.40 " "
700 "	30 "	60 "	.70 " "

On the basis of .2000 gram of antimony taken .4 c.c. of the sodium thiosulphate would be equivalent to about 1.2 per cent. of antimony. These results showed that as the concentration of the hydriodic acid was increased iodine was liberated in increasing amounts, probably due to the action of dissolved oxygen on the large excess of hydriodic acid present.

The foregoing experiments lead to the conclusion that the reduction of antimony by hydriodic acid as in the sodium thiosulphate titration is as complete as by the other methods, and that the reduction is complete in all. However Weller in his original paper states that he obtained good results when he distilled over the iodine and titrated it. Also Herroun * by direct titration considers the method accurate. These higher results may be accounted for easily, when it is noticed, as in Weller's method, that on heating a solution of potassium iodide acidified with hydrochloric acid (containing dissolved oxygen), a considerable amount of iodine is set free even when no antimony is present to be reduced, and also when the very strongly acid solution of the antimony used by Herroun is taken into account. In a few experiments tried to determine whether higher results would be obtained with stronger acidification, it was found that as the amount of acid was increased higher results were obtained till, when 150 c.c. of concentrated hydrochloric acid was added to 600 c.c. of the solution of antimony, the titration gave exactly theoretical results.

Incomplete reduction thus did not explain the 1-per-cent. discrepancy. Further experiments were undertaken to test more fully the effect of oxygen dissolved in the solution, also whether mass action was affecting the results.

To test the result of removal of air, a solution of the antimony was made in the usual manner, this diluted to 500 c.c. or 600 c.c.

and boiled for some time to remove the dissolved oxygen, the solution then cooled in an atmosphere of carbon dioxide and the titration made under varying conditions as to temperature concentration of hydriodic acid, antimony, etc., as indicated by the following table.

	Sb Taken.	Temp.	Atmosphere.	KI.	Sb Found.	Error.
(1)	.2198	18.3° C.	air	3 grams.	.2175	1.01 %
(2)	.1973	26.5 "	CO_2	3 "	.1951	1.09 "
(3)	.1886	20 "	CO_2	10 "	.1860	1.38 "
(4)	.2122	21 "	CO_2	20 "	.2099	1.09 "
(5)	.2091	22 "	CO_2	40 "	.2075	.76 "
(6)	.3976	20 "	air	3 "	.3936	1.00 "
(7)	.6095	23 "	air	3 "	.6028	1.11 "
(8)	.8072	20 "	air	3 "	.7971	1.25 "
(9)	.2236	0 "	air	3 "	.2207	1.20 "
(10)	.2429	0 "	CO_2	3 "	.2403	1.10 "

No. 1 above is given simply for comparison. In 2, 3, 4 and 5 where the titration was made in the absence of dissolved air and in an atmosphere of carbon dioxide it is seen that varying the quantity of potassium iodide under these conditions had no effect on the liberation of iodine. In 6, 7 and 8 where the quantity of antimony was varied, the titration showed no change in the usual liberation of iodine. In 9 and 10 the titration was made in air and in carbon dioxide at 0° C., with no variation in the amount of iodine set free.

Clearly mass action does not seem to be the cause of the discrepancy from the theoretical. It should be noted however that at 0°, especially in the absence of oxygen, the iodine was liberated more slowly than at the usual temperature, and also that increased acidification in the absence of oxygen did not affect the amount of iodine liberated, except that with very strong acid the potassium iodide is less soluble, and consequently the iodine appeared to be liberated slowly.

The error of 1 per cent. is as yet unexplained, and the investigations are still in progress.

Accuracy and Adaptability of the Herroun-Weller Method for Ordinary Use.

Of the volumetric methods for antimony the direct titration of the iodine liberated by the addition of potassium iodide to antimony

* *Chem. News*, 1882, 45, 101.

solution after oxidation by nitric acid and potassium chlorate in hydrochloric acid solution, no tartaric acid being used, gives as accurate results as Mohr's method, and the method is much simpler to carry out. Tin, if present, does not interfere, as it would be oxidized to the stannic condition, and is not reduced by hydriodic acid. This was shown to be true by a number of experiments where tin was added to the antimony.

The 1 per cent. error constantly found, it will be noticed, is calculated on metallic antimony and in the analysis of an ore if only 25 per cent. or less of antimony is present the method would be within the limits of error in technical work. For great accuracy a correction of 1 per cent. on the antimony found can be added, when the standard of the "hypo" is calculated from iodine copper or potassium dichromate.

Two ores analyzed gave as follows:

Ore Taken.	Per Cent. Sb Found.
(1) .9847	18.65 Per Cent.
(2) 1.0462	18.68 "
(3) .8966	18.63 "

The ore contained arsenic and iron. In the first two cases the arsenic was distilled over by Fischer's distillation, the antimony then precipitated by hydrogen sulphide; this sulphide dissolved by HCl, HNO_3, $KClO_3$ and titrated as usual. In the third case the arsenic was separated by precipitation in 1.17 sp. gr. solution of hydrochloric acid.* A gravimetric determination of this ore gave 18.74.

Another ore containing no arsenic gave results as follows: 45.35 per cent., 45.21 per cent., 45.25 per cent. There is no trouble whatever to get concordant results and the end point is all that can be desired.

Conclusions.

The conclusions to be drawn from this work are:

1. Antimony is completely oxidized by nitric acid and potassium chlorate in hydrochloric acid solution, in the absence of tartaric acid.

2. Antimony is completely reduced by boiling with sulphur dioxide in open or closed vessel; or by sulphur dioxide and potassium bromide; or by potassium iodide in cold hydrochloric acid solution.

* Pathuson's Method.

3. The direct titration of antimonic solutions by Herroun's-Weller method gives very concordant results, but is 1 per cent. low, calculated on metallic antimony with atomic weight 120.4.

4. The conditions for getting this result must be within rather narrow limits and are as follows:

(*a*) .2000 to .2500 gram of antimony (calculated as metal).

(*b*) Oxidized and dissolved by hydrochloric acid, 1 c.c. nitric acid, and successive portions of potassium chlorate, in the absence of tartaric acid, solution reduced to 50 c.c., and 15 c.c. or 20 c.c. of concentrated hydrochloric acid added, then made up to about 700 c.c. by the addition of water.

(*c*) 3 or 4 grams crystals of potassium iodide added to the cold solution.

(*d*) Liberated iodine immediately titrated by sodium thiosulphate checked against copper, potassium bichromate, or iodine.

5. The error of 1 per cent. is not due to mass action, but is yet unexplained.

This work was undertaken at the suggestion of Prof. Edmund H. Miller and carried out under his direction.

THE ROSSIE LEAD VEINS.*

By C. H. SMYTH, Jr.

Were it not for the specimens of calcite, galena and pyrite which they have supplied to mineral collections, the old Rossie lead mines of St. Lawrence County, New York., would now hardly be remembered beyond their own neighborhood. But, although of no present commercial importance, they are of sufficient geological and historical interest to merit some consideration.

Beck† and Emmons‡ examined the locality not long after the opening of the mines, when, of course, many data could be obtained that are not now available. The following notes are intended to supplement the work of these earlier writers.

Emmons, being more particularly concerned with the geology of the veins, described their chief features in some detail and gave

* Based upon field work done for the State Geologist of New York.

† L. C. Beck, "Mineralogy of New York," pp. 48–50, and "First Annual Report New York Geological Survey," pp. 54–55.

‡ E. Emmons, "Geology of New York," Pt. II., pp. 354–360.

an interesting figure of the largest, the "Coal Hill," vein as it appeared when first worked.

The veins, of which there are four, occur in a flat-topped hill which is rather precipitous toward the east, but has gentler slopes on the other sides. This hill is composed of gneiss, which Emmons described as "distinctly stratified," apparently implying a rock of sedimentary origin. As a matter of fact, two varieties of gneiss, both quite massive, are present, one dark gray and rather fine-grained, the other pink and with a tendency to porphyritic texture. In the immediate vicinity of the Coal Hill vein, these two varieties of gneiss are not clearly defined, but farther north, toward the Victoria vein they are shown to be quite distinct. The pink gneiss is younger than, and intrusive in, the gray gneiss cutting sharply through it and holding many inclusions torn from it. The included fragments are sometimes angular, but more often elongated and with angles rounded. In thin section, the pink gneiss is seen to be made up of the normal constituents of a biotite granite, quartz, orthoclase with a little acid plagioclase, biotite and the usual accessories. A condition of strain is indicated by much undulatory extinction, but there is little granulation. The rock is a slightly foliated granite, intermediate between the wholly massive granites and the typical gneisses of igneous origin, so widespread in this region.

The true character of the older gray gneiss is less certain. The rock is rather massive and quite uniform in composition and texture, features common in the igneous gneisses; and with these it is probably to be classed, although the possibility of a sedimentary origin can not be positively denied. Under the microscope it differs decidedly from the younger rock. Quartz is less abundant, while plagioclase shows a marked increase, and at the same time gives larger extinction angles, indicating more basic species. Hornblende, wholly lacking in the first rock, is abundant in this, while biotite is quite subordinate. Magnetite is present in notably large quantity, together with a little pyrite. Thus, the rock is more basic than the granite-gneiss, showing an affinity with the diorites.

Both of the foregoing rocks are cut by pegmatite, which is probably closely related to the granite-gneiss, and certainly long antedates the period of vein formation.

The consolidation and metamorphism of the gneisses were deep-

seated phenomena, occurring in the zone of flowage. The production of the vein fissures involved very different conditions, when a long period of erosion had removed a great thickness of overlying rocks, thus bringing the gneisses into the zone of fracture. It does not follow, however, that the gneisses may not have been fissured when at considerable depth, since, for rocks of this class, the zone of fracture is very thick.

Whether or no the fracturing was attended by any large vertical displacement is not shown, although the fissures are evidently due to faulting. The nature of the rocks is such that faults of some magnitude might give no measure of the amount of throw.

The veins cut across the foliation of the gneisses, at a high angle, approach parallelism with one another, and have a strike of about N. 80 W. The Coal Hill vein being the largest of the group, may be taken as the type of all, and considered with such detail as is admitted by the somewhat meagre data procurable under existing conditions.

The vein varies from two to six feet in width, is nearly vertical, and sharply defined. As is well known, the gangue is coarsely crystalline calcite, carrying galena, with a little pyrite, and small amounts of sphalerite and chalcopyrite.

The character of the minerals of the vein is too familiar to require any consideration here; it need only be remarked that, as stated by Emmons, the galena, though quite bunchy and irregular, is on the whole more abundant towards the middle of the vein.

Some parts of the vein, particularly along the margins, contain abundant inclusions of the wall rock, forming a breccia cemented by the vein-stuff. The fragments vary greatly in size, and are sometimes angular, while in other cases they are rounded and have clearly suffered much loss by attrition or solution, or both.

Many fragments are quite unaltered and indistinguishable from the wall rock, while others appear to be more or less thoroughly changed into a mass of alteration products, containing strings and scattered grains of calcite and galena. The unchanged and the altered fragments are intimately associated.

The alteration product is light grayish-green and rather fine grained. On weathered surfaces it appears to be quite sharply differentiated from the mass of the unchanged rock on the one hand, and the vein-stuff on the other. But fresh fractures show a more gradual transition on both sides. In extreme cases, the al-

teration product is irregularly mingled with the vein stuff, showing no fixed outline. As the alteration is confined to the margins of larger fragments, to cracks passing through them, and to thoroughly crushed parts, there can be little doubt that its amount is chiefly dependent upon degree of comminution. As to how much chemical change has actually taken place in the rock fragments, the evidence at hand is very unsatisfactory. To the unaided eye there is indication of much alteration, but closer examination, while showing alteration beyond doubt, tends toward the view that it has been very limited in amount. Under the microscope, fragments that, to the unaided eye, appear thoroughly altered, show a large amount of material which, beyond crushing, shows no change. Perfectly fresh, angular or rounded fragments of the various minerals lie in calcite and galena, with no trace of corrosion or alteration; and such fragments are decidedly in the majority. But, on the other hand, many grains of feldspar have been bleached and some of them have been partly replaced by calcite and galena. The edges of these feldspar grains are ragged, and pieces in perfect optical continuity are sometimes separated from each other by an intervening strip of calcite or galena. The latter mineral shows a tendency to develop along cleavages of the feldspar, or it may appear as a fine black powder scattered all through the grain.

But, on the whole, less actual replacement is apparent than would be inferred from superficial inspection. As shown below, there is reason for believing that much of the finest rock powder was replaced and the microscopic evidence does not disprove this view, but for the coarser grains a mere bleaching of the feldspar is the prevailing change.

This question of the amount of replacement is of much interest in connection with the history of the vein, and it is unfortunate that the direct evidence bearing upon it is so meagre. At present, it is clear that the vein-stuff acts as a cement and support for the fragments of wall-rock; were the former removed, the latter would drop down in the fissure. Prior to the deposition of the vein-stuff, its place must have been filled by something else, and it is evident that this must have been finely powdered wall-rock, which apparently has since been replaced by vein-stuff.

If this explanation is the true one, the condition of the fissure prior to the replacement is illustrated by a fault breccia in the

gneiss at Hammondville, Essex County, N. Y., shown to the writer by Prof. J. F. Kemp some years since. The country rock is a red gneiss somewhat resembling that at Rossie. Along a fault, fragments of this rock, of every shape and size, are scattered through a fine-grained dark green matrix, which consists of rock powder mixed with chlorite and other alteration products.* Had this fissure become a channel for the circulation of ore-bearing solutions, the condition would have been favorable for the formation of a vein closely analogous to those at Rossie. That chloritic alteration products may sometimes form an intermediate step in the replacement of crushed rock by vein-stuff is clearly suggested by this case, but thus far no evidence bearing upon the question has been found in the Rossie material.

But while between the Hammondville brecciated zone and those parts of the Rossie vein that are filled with rock fragments, there is a striking analogy, it remains a fact that other parts of the vein are quite free from inclusions, consisting of the vein minerals alone, with frequent druses of considerable size, lined with large and perfect crystals. Even were the evidences of replacement much stronger than they are, it would be difficult to ascribe such results to the process, and there can hardly be a doubt that the filling of preëxistent cavities has been the chief factor in vein formation. Cavities were doubtless formed at many points along the fracture, when elsewhere the interwall spaces were filled with breccia. Other cavities may possibly have resulted from solution before vein deposition began. But something more is needed to account for the vein as a whole, and perhaps the best explanation is afforded by the assumption that the vein formation consisted of at least four stages.

At first, the fissure, more or less blocked with breccia, was formed. Next, the breccia was cemented, perhaps first by chloritic alteration products but more probably directly by vein-stuff, cementation being accompanied by replacement. Then followed another movement along the fault, with the production of an open fissure, which, in the fourth and last stage, was filled by a further deposition of the vein minerals.

Such an explanation as this accounts for the facts at hand without demanding too much of replacement, and while, as stated

* Cf. J. F. Kemp, "Preliminary Report on the Geology of Essex County," Annual Report of the State Geologist, 1893, p. 456.

above, there is good reason for believing that this process has been a factor in the formation of a vein, judging from present data, it has played a very minor part.

As to the source of the vein minerals, there is very meagre evidence. The frequent association of ore deposits with igneous rocks holds good here, and yet there is no sufficient reason for concluding that the association in the present case is of a genetic nature. From what has been stated above, it is clear that the vein was filled long after the cessation of igneous activity, under totally changed conditions, so that it is not impossible to look to the granite magma as a source of hot mineralized solutions. If the gneisses of the walls furnished the vein materials, it must have been by the action of ordinary ground waters, having the normal temperature for the depth involved. How difficult it would be to prove this origin for the vein minerals, it is needless to say.

In view of the character of the minerals, both gangue and ores their source is, perhaps, more apt to be found in the crystalline limestones which are frequent in the vicinity, and outcrop only a few rods east of the ridge in which the veins occur.

Of the frequent association of the metalliferous minerals of the vein with limestones, it is unnecessary to speak, and it is well known that these minerals are present and have been mined at several localities in the crystalline limestone of this region, although the nature of the ore deposits has not been determined.

The same rock would, of course, furnish the calcite gangue, and thus it affords a possible source for all the materials of the vein. The igneous intrusions of this region are frequently in the form of heavy sheets, so that it is quite possible that crystalline limestone lies directly below the outcrop of the veins. But this is, of course, not essential to the hypothesis, since the movement of the ground waters has a large horizontal component.

In this connection interest attaches to a vein which was first called to the writer's attention, some years since, by his assistant, Mr. D. H. Newland. About a mile north of Redwood, Jefferson County, the R. W. & O. railroad makes a deep cut through the Potsdam sandstone, affording a section some five or six hundred feet long. Throughout the section, the sandstone is much crushed but the strata remain nearly horizontal, and the faulting doubtless present is not sufficient to bring in any other horizon.

At one point in the section, there is a fissure, from four to six

feet wide, filled with calcite carrying galena, pyrite and sphalerite. Several smaller veins occur, there being, indeed, an irregular crushed zone about forty feet wide, within which the vein-stuff and sandstone fragments form a breccia.

Several small openings on the main vein show that some prospecting has been done, but when or by whom is unknown to the writer.

This locality is only seven miles from the Rossie mines, and in view of this proximity and the similarity of the veins both in composition and structure, it is not improbable that they belong to one period of vein formation. At Rossie, erosion has removed the Potsdam so that the relation of the veins to this horizon can not be determined, but it has already been shown that they are long subsequent to the intrusion and metamorphism of the pre-Cambrian gneisses, and, at least, there is nothing to indicate a date earlier than post-Potsdam.

But aside from affording this suggestion as to the possible age of the Rossie veins, the Redwood vein is of interest in its bearing upon the hypothesis of the derivation of the vein minerals from the crystalline limestone. It is hardly possible that the immediate wall rock of the Redwood vein should be the source of the vein minerals, since a rock less likely to furnish them could scarcely be found. There is no apparent reason for believing that the minerals came primarily from above and so it becomes necessary to look below for a source.

The writer's preliminury geological map * of the region shows a belt of crystalline limestone which passes under the Potsdam sandstone near the west shore of Butterfield lake and appears again from beneath the sandstone just to the west of Redwood. If, as is almost certain, this belt is continuous under the Potsdam, it must pass almost, if not directly, under the vein in the railroad cut. Water circulating through the limestones, under pressure and seeking an exit toward the surface would find a ready channel through the crushed zone of the sandstone, depositing during its ascent mineral matter taken up from the limestones. This explanation of the formation of the vein is sufficiently in harmony with all the facts in the case, to be regarded with some confidence, and it gives added strength to the hypothesis as applied to the Rossie

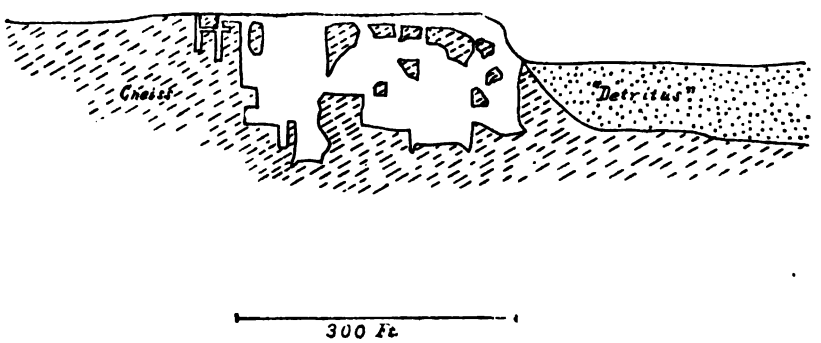
* "Nineteenth Annual Report State Geology of New York," facing p. 85.

veins. In both cases it is probable that the vein minerals came from below, and in both cases the crystalline limestone, known to be the carrier of the vein minerals, is present, at Redwood probably directly below the vein, at Rossie in the immediate vicinity and perhaps directly below.

While these facts suffice to justify the hypotheses as a tentative explanation of the problem in hand, they do not, of course, afford a final solution. It is quite possible that the vein materials were derived from a source far below the limestones, and that the ore deposits in the latter are contemporaneous with the veins.

In neither the Rossie nor the Redwood veins is there any evidence as to the agents of precipitation or the nature of the reactions involved. Were the mines in operation, light would doubtless be shed upon these and many other obscure points.

Mining on the Coal Hill vein was begun in 1836. Early in 1837 a large force was employed and the enterprise was pushed with great energy. The ore raised was, for the most part, smelted in a furnace about a mile distant from the mines. At about the same time the other veins were opened, two companies being in the field. In the years 1837 and 1838 the Coal Hill vein produced 1,625 tons of lead, according to the books of the smelting company.



In view of the fact that, at this time, the country was practically a wilderness with only the crudest means of transportation, it is not surprising that mining operations ceased at the end of three years. It is probable that the mines were never worked at a profit, although the large land owners interested may have gained indirectly by the operations.

Some idea of the extent of mining is given by the accompanying sketch, drawn from a figure in Hough's "History of St. Lawrence

and Franklin Counties." The unshaded part of the sketch represents excavations. As the section is longitudinal, it is evident that what is designated gneiss as in the original figure, is, in reality, the vein. Detritus probably stands for glacial material. The same book gives, pages 455–467, many additional details in regard to the history of the enterprise.

In 1852, the Great Northern Lead Company leased the mines, put in new machinery and planned work on a large scale. What was the outcome of this venture the writer has been unable to learn. Apparently success did not attend the undertaking for, according to Mr. C. A. Parker, of Gouverneur, to whom the writer is indebted for information in regard to the matter, the Rossie mines were worked during the Civil War by the Mineral Point Lead Mining Company, which also had mines at Mineral Point, on the south shore of Black Lake. At that time the high price of lead had started up at least two other mines in the region, one near the village of Macomb and the other in the town of Gouverneur, near Beaver Creek. How long these operations continued, or what was the product has not been learned. But it is probable that no mining has been done since the close of the war.

At the time of the writer's visit, everything at the mines, with the exception of the white Potsdam sandstone chimneys was in a ruinous condition, plainly testifying to many years of neglect.

HAMILTON COLLEGE, CLINTON, N. Y.

LABORATORY NOTES FOR STUDENTS IN PRACTICAL ELECTROCHEMISTRY.

BY S. A. TUCKER,
OF THE CHEMICAL DEPARTMENT, COLUMBIA UNIVERSITY.

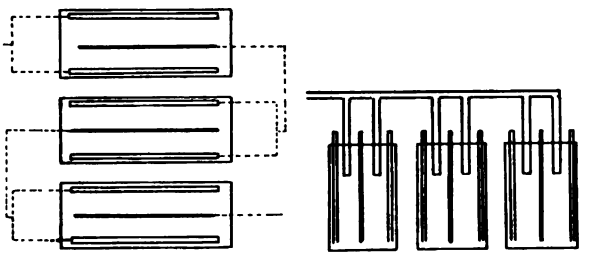
The following notes were the outcome of a desire on the part of the Electrical Engineering Department of Columbia University to give the students familiarity in the practice of electrochemistry, and particularly in the use of the electric furnace. The limited time at the disposal of the students made it necessary to select from a large number of experiments which are given in the regular course offered by the Chemical Department such as would embody the general principles which underlie the more important processes in operation on a large scale.

Of these experiments only two have been included in electrolysis from aqueous solution — the deposition of copper from impure copper liquors and the electrolysis of saline solutions, and these have been taken entire from the admirable text-books of Oettel * as nothing could be found which would give a better understanding of the electrolytic copper and alkaline industries.

The other experiments are such as have been in use in the regular course for some years past.

WORKING OF A COPPER LIQUOR CONTAINING ARSENIC.†

The liquor to be worked contains 40 grams of copper as sulphate, and 10 grams of arsenic per liter.



Apparatus for Purification of Copper

The problem is to deposit the copper without the arsenic. Two considerations are to be observed, current density and agitation. When the current density is high, very little time is allowed for selection from among the various bodies in solution. Hence working at a low current density there is more chance for the copper to be deposited in a pure form.

The liquid at the kathode from which the copper has been deposited becomes lighter and therefore rises to the top, and will necessarily contain more of the arsenic in proportion to the copper. Agitation will prevent this, and will tend to give copper in a purer form in the deposit.

Execution of Experiments. — Two rectangular glass jars, one containing two lead plates and one thin copper plate 10 by 10 cm., to be used for the copper depositing; the other to be used as a copper voltameter. A horizontal stirring attachment is used on the copper depositing cell. This should be so arranged that two glass rods are made to move between the plates 30 times per minute.

* Oettel, "Exercises in Electrochemistry, Electrochemical Experiments," translated by Edgar F. Smith, P. Blakeston Son & Co., Philadelphia.

† Oettel, "Electrochemical Experiments," p. 118.

A current density for the first experiment will be about 75 amps. per sq. m., and the experiment carried on until the arsenic begins to show in the copper deposit. This may take 10 hours. The voltage is taken during the operation, and then the same experiment is to be repeated using a current density of 36 and 18 amps. per sq. m., in each case. The copper deposited in the copper voltameter is to be weighed in each case.

From the data so obtained the calculation of a plant for actual working such a liquor may be made.

Electrolysis of Salt Solution With the Use of a Diaphragm.*

The Apparatus. — This consists of a beaker of about 700 c.c. capacity in the middle of which stands a porous cup. This cup is fitted with a tight rubber stopper through which passes two glass tubes. One of these tubes is used to conduct the chlorine, oxygen, etc., to the apparatus for its analysis. The other has a platinum electrode sealed into it. The portion of the porous cup standing outside the liquid is paraffined to prevent the escape of the gas. The kathode is of the sheet iron bent so as to enclose the porous cup.

The Experiment. — The solution used is 20 per cent. NaCl. This is filled into the inner and outer compartments. The outer, that is the beaker, is roughly calibrated as to its holding contents.

A current of from 3 to 5 ampères is used and an analysis is to be made every hour of the escaping gas and the kathode liquid. The gas is to be analyzed as follows: About 50 c.c. of the gas are taken into a Hempel's measuring burette, and then the absorptions made with potassium hydrate for the chlorine and with the phosphorus pipette for oxygen, the small residue of gas remaining is nitrogen. In the calculation, this residue, together with one fourth its volume of oxygen is recorded as air.

Ten cubic centimeters of the kathode liquid is removed and its alkalinity determined with standard acid. The neutralized portion is diluted to 200 c.c., and 20 c.c. is then titrated with silver nitrate for the chlorine.

The quantity of titrating liquid (H_2SO_4 and $AgNO_3$) for each successive cubic centimeter of the electrolyte taken constantly increases in consequence of the transference of sodium to the outer solution. The quantity of NaOH may be calculated from the observed alkalinity and the volume of the kathode liquid.

* Oettel, "Practical Exercises in Electrochemistry," p. 52.

The current yield of NaOH diminishes with the rising alkalinity of the liquid, and the liberated chlorine at the same time becomes proportionally rich in oxygen. The changes in the yield are determined separately for each successive hour.

In Order to Get at the Current Efficiency. — The current may be held constant during each period, or a copper voltameter is put in the circuit, which is probably the better way.

Note the pressure with every variation in current density, determine directly from the decomposition pressure Z, and calculate from this, from the fall of potential V in the bath, and from the current strength i, the resistance w of the bath, by the formula

$$V = Z + i \cdot w.$$

Also calculate, from the results of the experiment the production of NaOH from the end liquids, with varying alkalinity per horse power hour.

Electrolysis of Fused Lead Chloride.

See McMillan-Borchers, "Electric Smelting and Refining," p. 331. Oettel, "Practical Electrochemistry," p. 74.

This experiment may easily be carried out on a small scale, and with the data so obtained a plan can be projected for working on a large scale.

A sheet-iron crucible about 2½ inches at the top constitutes the kathode and at the same time serves as a container for the electrolyte.

The lead chloride is fused down in the crucible over the lamp, when it is in a quiet state of fusion, a carbon rod attached to the positive pole is lowered into the bath.

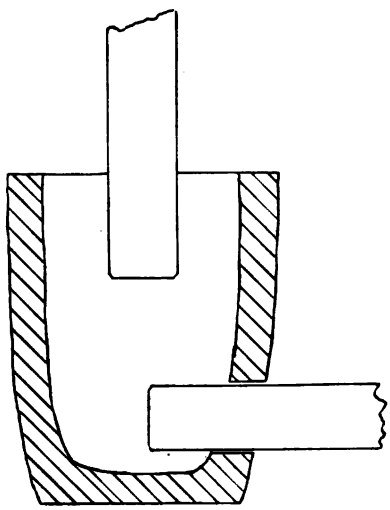
Using 5 to 10 ampères for an hour will give a fair size button of lead. The button is to be weighed, and the efficiency of the experiment determined from this weight and the readings of the ampèremeter and voltmeter during the experiment.

From these data calculate the power and number of baths required for the daily production of 1,000 kg. of lead, assuming that 500 ampères are to be conducted into each bath.

Preparation of Calcium Carbide.

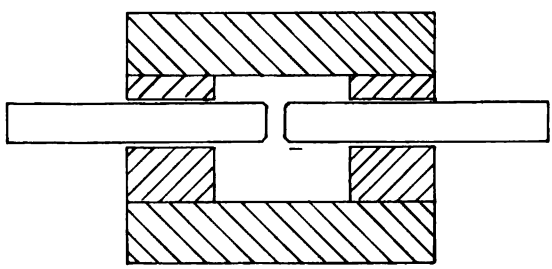
See Moissan, "Le Four Electrique," p. 290. Lewes, "Acetylene." Tucker-Moody, "Improved Electric Furnace for Laboratory Use," *Jour. Am. Chem. Soc.*, Vol. XXIII., July, 1901, p. 473.

This is first made in the vertical type of electric furnace, which is practically the same as that at first used by Willson in the manufacture of carbide. It consists of a carbon crucible about 5 inches diameter at the top and 7 inches high, a hole being bored through the side to admit one electrode, while the other is suspended vertically.



Vertical Furnace for Carbide

The advantage of such a furnace on a small scale is that it enables one to see what is going on and that the arc may be brought to bear on any particular part of the charge at will, much as a blowpipe is used. The chief drawback is in the loss of heat by radiation. The charge is composed of 56 parts of lime oxide (CaO) and 36 parts of powdered coke. A charge of 200–300 grams is sufficient and should be acted upon at 150 ampères, 50–60 volts



Horizontal Furnace for Carbide

for about 6 minutes. This results in a fair yield of carbide, which should have a fine bronzy crystalline appearance. Next make the same in the horizontal type of furnace.

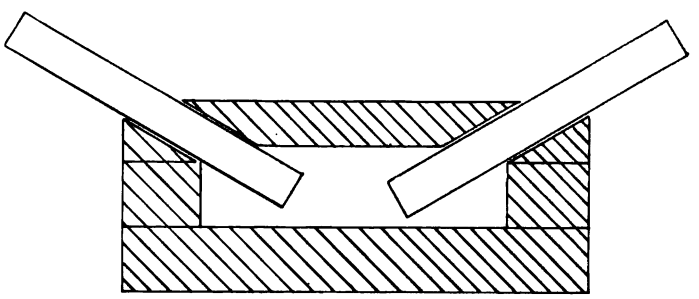
This furnace is of the Moissan type but differs from it in being made entirely of carbon. It is built of carbon bricks allowing a rectangular space of 3 x 2½ inches by 4 inches deep. The electrodes of Acheson graphite, 1¼ inch diameter, are passed through holes at each end and must be carefully insulated from the furnace by asbestos bushings. The whole furnace is clamped together and preferably covered with asbestos board.

Aluminium Bronze (Cowles Process).

See Richards, "Aluminium," p. 329, etc.

The reduction of alumina (Al_2O_3) by carbon alone seems an impossibility, but when some other metal is present, such as copper, iron, etc., the reduction may be effected in the electric furnace, the aluminium then alloying with the particular metal present. The furnace used is of the type as used by Cowles, and is composed of fire brick, the electrodes being inclined.

The charge being introduced the whole is covered as much as possible with fire brick for heat insulation. The charge is made up of 25 parts of alumina, 12 parts of powdered coke, and 50 parts of granulated copper; the whole thoroughly mixed and being made up to 300–400 grams. This is acted upon at 250–300 ampères, 50–60 volts for 12–15 minutes. The product is a bronze which should be remelted and cast so that its physical properties may be studied.



Furnace for Aluminium Bronze

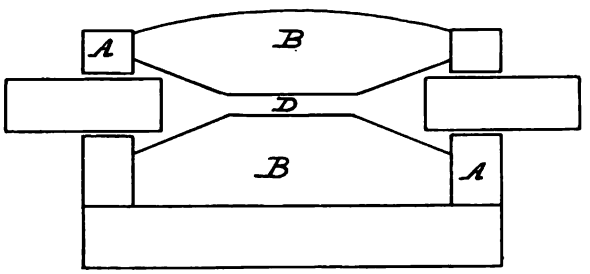
Carborundum, Carbide of Silicon.

See C. A. Koln, *Jour. Soc. Chem. Industry*, 1897, p. 863; Moissan, "Le Four Electrique," p. 351.

This compound, which has the formula SiC, was discovered by E. G. Acheson in 1891 and was put on a commercial basis by him at Niagara Falls.

The furnace used is of the horizontal resistance type, and is built up in such a way that between the electrodes a partial conductor is placed. Thus in Fig. 1, *D* represents the core which on a large

Fig. I.



Furnace for Carborundum.

scale is composed of granular carbon or coal, *B* is the charge proper, while *A* is the furnace wall consisting of brick.

The charge is composed of:

Coke	34.2	parts by	weight.
Sand	54.2	"	"
Sawdust	9.9	"	"
Salt	1.7	"	"

and is thoroughly mixed.

The furnaces for working upon a large scale are built for 15 tons of the charge, the core forming about 3 per cent. of this.

The pressure is at first high, being 190 volts as the resistance of the cold carbon is considerable, but in a short time falls to 125, at which it remains constant to the end of the run. The amperage is 6,000 and it takes 36 hours for working such a charge.

In taking down the furnace the outside layer is composed of amorphous silicon carbide, of which there is about 40 per cent.

Its amorphous nature is due to the lower temperature prevailing as the distances from the core increases, and if the run is kept up for shorter periods may constitute the sole product.

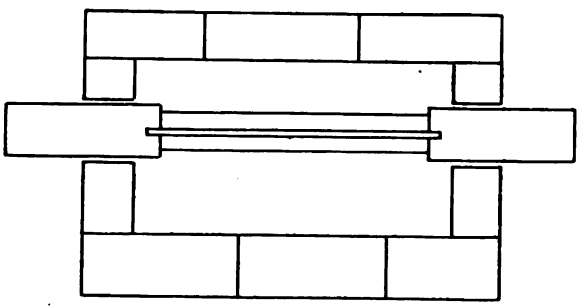
Below this is a well-defined crust of crystalline carbide, which consists in fine iridescent crystals, some of which are a half inch in diameter. The color of these crystals is due to impurities such as iron, for Moissan has prepared pure silicon carbide which is colorless.

Beneath the crystals graphite is found and this was the origin of the artificial graphite which is now coming so largely into use for electrochemical purposes.

In working the process on a small scale, the above proportions for the charge are taken, the whole being made up to 800–1,000 grams.

The electrodes in Fig. 2 are 2 inches in diameter and are connected together by a thin stick of carbon in order to avoid difficulty

Fig. 2.



Furnace for Carborundum.

in starting. This will burn out after a short time, and then the core will act as the resisting medium. The walls of the furnace are of fire brick, the bottom and sides being filled with the charge.

Surrounding the thin rod is placed about ¾ inch diameter of coarse crushed carbon or coke, the rest of the charge being filled in all around and packed to some extent. The top is covered as much as possible with fire brick to retain the heat.

The current used will be 350 ampères at 60 to 70 volts and must be kept up for an hour or one hour and a half.

Such a method of working will naturally not give as fine a product as is to be obtained on a large scale, but the different layers are to be looked for, and the crystalline nature of the carbide well shown although the crystals will be small.

The uses of carborundum are chiefly for abrasive purposes, and it is now made in all forms adapted to grinding machinery.

The lower grades of carbide have found considerable application as heat-resisting material for which purpose it has a high value.

Preparation of Aluminium (Hall's Process).

See Richards, "Aluminium," p. 372. McMillan-Borchers, "Electric Smelting and Refining," p. 142.

This is an electrolytic process in which the electrolyte consists of a fused bath of aluminium and sodium fluorides. According to Hall's patent the bath should contain:

Sodium fluoride	33.2 per cent.
Aluminium fluoride	66.8 "

But these exact proportions do not seem to be essential.

The mineral cryolite, which is a double fluoride of aluminium and sodium, furnishes a source of these fluorides in the natural state, and is well adapted to the purpose. It is composed of:

Aluminium fluoride	40.25 per cent.
Sodium fluoride	59.75 "

This mineral in a fused condition dissolves alumina (Al_2O_3) to the extent of about 25 per cent., which important fact appears to have been discovered by Hall in this country and Herolt in France about the same time.

Hall was the first however to adapt it to the commercial production of pure aluminium, and the United States patent was accordingly granted to him. As operated on a large scale the kathode is a rectangular tank of wrought iron lined with carbon, about 6 feet long, 3 feet wide and 2½ feet high. The anodes are of round carbon rods of which there are several, with a suitable device for adjusting their depth in the bath.

The electrolyte is fused down by the arc and the alumina is gradually added, no external heat being necessary. As the alumina is decomposed by the current the resistance of the bath rises, and hence gives a good indication as to when the addition of more alumina is to be made. The aluminium collects at the bottom in a suitably formed cavity and from this is ladled out, the furnaces being kept in continual operation.

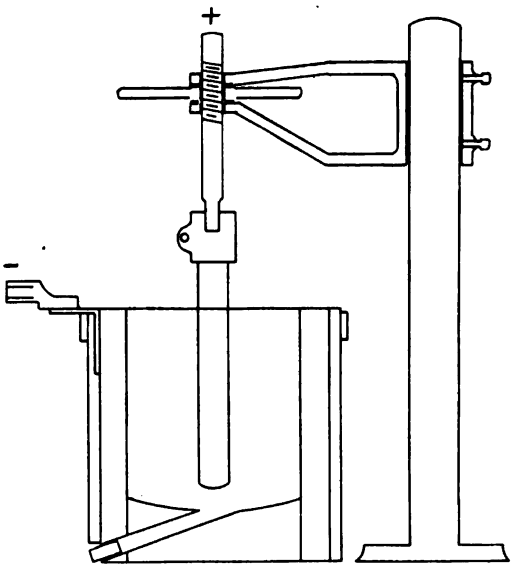
The ends of the anodes are kept from a half inch to an inch from the surface of the kathode. The consumption of the carbon amounts to less than a pound per pound of aluminium produced. Oxidation of the carbon takes place according to the reaction

$$Al_2O_3 + 3C = 2Al + 3CO.$$

In regard to the efficiency of the process, Richardson's calculation based upon two vats taking 1,800 ampères is of interest. The theoretical yield is 56.4 pounds of aluminium per day. The actual yield was 50 pounds, this gave an efficiency of nearly 90 per cent. But 30 per cent. of the current is used in decomposing the alumina,

inasmuch as of the 9 volts taken by the bath but 2.5 volts are used in this decomposition. The actual efficiency is therefore 90 per cent. of 30 which is 27 per cent. The rest appears as heat in the bath.

To follow this process on a small scale, a carbon crucible turned from Acheson graphite is used for the kathode, and is made large



Furnace for Aluminium.

enough to hold a kilo of cryolite. This is covered on the outside with asbestos for heat insulation, and is provided with a tap hole at the side which connects with the cavity at the bottom.

The cryolite must be selected as it always contains specks of carbonate of iron or sulphide of lead. This is then fused down with the arc from a vertical carbon which is the anode, and when in a quiet state of fusion purified alumina is added to the extent of 15 to 20 per cent.

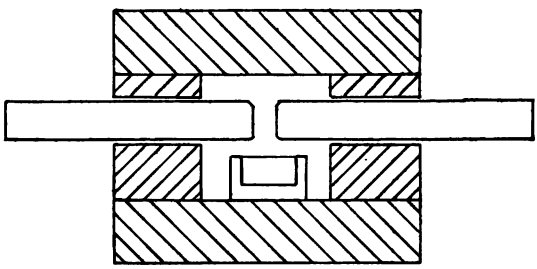
The electrolysis is conducted for an hour to one hour and a half, the vertical carbon being carefully adjusted so as to regulate the voltage from 9 to 10 volts. The current used may be from 150 to 200 ampères. A portion of the charge is then tapped off into a small iron pot by removing a carbon plug in the crucible. This is kept separated from the main portion of the charge which is allowed to run into a larger iron vessel, so that the aluminium may be retained by a smaller part of the charge and thus be easily

separated after it has solidified. Working in this way from a new bath the aluminium will not be pure, but it should be carefully separated, weighed and its properties studied; and the efficiency of the process calculated from the noted current, pressure and time.

Preparation of Metallic Chromium.

See Moissan, "Le Four Electrique," p. 206. McMillan-Borchers, "Electric Smelting and Refining," p. 306.

This is best carried out in the horizontal carbon furnace, using a



Furnace for Chromium.

small graphite crucible, which is filled with the charge and placed directly under the arc.

The charge is composed of:

Chromium trioxide, Cr_2O_3	152 parts.
Carbon (powdered coke)	32 "

The contents of the crucible is then heated for about ten minutes at 300 ampères at 60 volts.

The resulting chromium will not be pure as it contains some carbon together with parts of the charge which may have escaped the action. The best pieces are again fused with the addition of a very little chromium trioxide in a graphite crucible which has been lined to some extent with the same oxide.

In this way a product should be obtained of much greater purity.

Note. — Chromium trioxide as it is sold generally contains some sulphur. It is therefore necessary to ignite it strongly upon an iron plate in the gas flame before making up the charge.

ON THE USE OF INFLUENCE LINES IN GRAPHIC STATICS. PART III.

By MYRON S. FALK.

Art. 13. Influence Line for Moments.

A line which indicates the variation of moment at any point in a beam under a single moving load, is a moment influence line. Let AB (Fig. 11) represent a beam of length l and let C be the

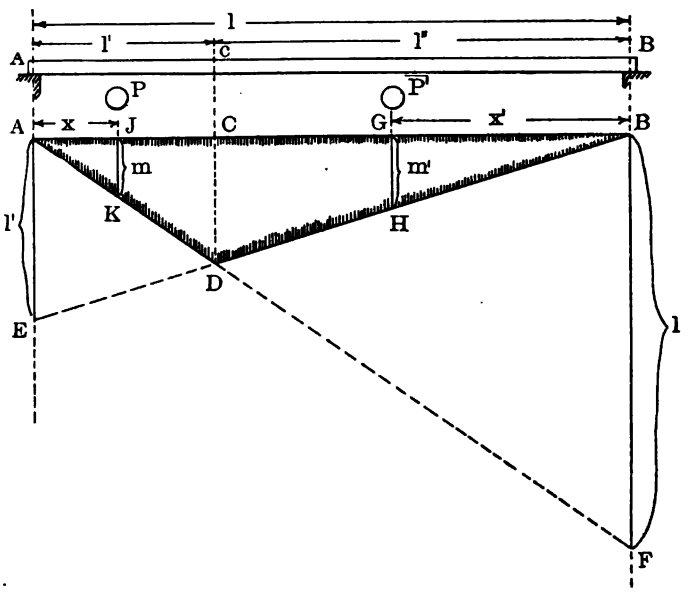


Fig. 11.

section which divides the beam into the two portions l' and l'' and about which moments are to be found. If a load P' be on the section l'' (at the point G, distant x' from B for instance), the moment M' about C equals the product of the left reaction by the length AC; that is:

$$M' = \frac{P'x'}{l} \cdot l' \qquad \text{Eq. (1)}$$

But if, as will be assumed for the present, the load is a unit load Eq. (1) takes the form

$$M' = \frac{x'}{l} \cdot l' \ldots \qquad \text{Eq. (2)}$$

Eq. (2) is the equation of a straight line and may be represented graphically as follows: Erect on the base line AB at A a vertical line AE equal in length to l', and connect E with B, the opposite end of the span. From similar triangles $GH : l' :: x' : l$; that is:

$$GH = \frac{x'}{l} \cdot l'.$$

Therefore any ordinate between CB and DB represents the bending moment at C when the load is placed directly over such ordinate. Similarly, for a unit load on l' between A and C, measuring x from A the moment equals

$$M'' = \frac{xl''}{l}, \qquad \text{Eq. (3)}$$

and the line AD, representing Eq. 3, graphically, is drawn by connecting F the end of a vertical of l'' erected at B, with A. The line ADB is thus an influence line for moments; from the construction it is evident that the corner D must lie vertically below the center of moments.

The area of the triangle ABD represents the value of the moment M at C for a uniform unit load over the entire bridge; its value is

$$M = \tfrac{1}{2} AB \cdot CD \qquad \text{Eq. (4)}$$

But $CD : AE :: BC : AB$, therefore

$$CD = \frac{AE \cdot BC}{AB} = \frac{l'l''}{l}.$$

Substituting this value in Eq. (4), $M = \frac{1}{2} l'l''$, and obtains its maximum value when

$$l' = l'' = \frac{l}{2}$$

in which case the moment becomes equal to

$$M = \frac{l^2}{8}$$

and therefore for a uniform load of intensity p over the entire bridge,

$$M = \frac{pl^2}{8}.$$

Art. 14. Criterion for Maximum Moment at any Section of a Beam.

By means of the influence line of the preceding article, the criterion for finding the position of a series of concentrated loads which will cause the maximum moment at any section of a beam, may be deduced. Let P' represent any load on l'' or the section BC (Fig. 11) and m' the value of the influence ordinate corresponding to this load; let P represent any load on l' and m the corresponding influence ordinate; let x' be the distance of P' from B, and x the distance of P from A; and let M represent the value of the moment at C for any position of the wheel loads. Then, if the sign Σ indicates the summation of terms of the same kind:

$$M = \Sigma(Pm) + \Sigma(P'm') \qquad \text{Eq. (1)}$$

The values of m and m' may always be expressed as follows:

$$m = \frac{CD \cdot AJ}{AC} = \frac{CD \cdot x}{l'}$$

$$m' = \frac{CD \cdot BG}{BC} = \frac{CD \cdot x'}{l''}$$

$$\therefore M = CD\left[\Sigma\left(\frac{P \cdot x}{l'}\right) + \Sigma\left(\frac{P'x'}{l''}\right)\right] \qquad \text{Eq. (2)}$$

If the loads advance a distance Δx to the left, the value of M becomes

$$M + \Delta M = CD\left\{\Sigma\left[\frac{P(x - \Delta x)}{l'}\right] + \Sigma\left[\frac{P'(x' + \Delta x)}{l''}\right]\right\} \qquad \text{Eq. (3)}$$

The change in the value of M is therefore

$$\Delta M = \Sigma\left(\frac{P \cdot \Delta x}{l'}\right) - \Sigma\left(\frac{P'\Delta x}{l''}\right) \qquad \text{Eq. (4)}$$

For a maximum or minimum $\Delta M = 0$, hence:

$$\frac{\Sigma P}{l'} = \frac{\Sigma P'}{l''}. \qquad \text{Eq. (5)}$$

If P represents $\Sigma P + \Sigma P'$, then Eq. (5) may take the form:

$$\frac{\Sigma P}{P} = \frac{l'}{l} \qquad \text{Eq. (6)}$$

in which form it has already been used in Article 5.

ART. 15. MOMENT INFLUENCE LINES FOR TRUSSES.

The moment influence line described in Article 13 can also be used for finding the variation of the moments in those kinds of trusses in which the center of moments is taken either at the panel points of the loaded chord, or in vertical lines through these points. The criterion of Art. 14 is then also directly applicable. But if the center of moments lies on a vertical which intersects the loaded chord line within the limits of a panel, the moment influence line already drawn must be subjected to a modification which is due to the redistribution of the loads within the panel to the panel ends.

In the case shown in Fig. 12, in finding the stress in the chord member BD in which case the center of moments C falls within the panel BD, the influence line drawn without reference to the existence of the panel, is only correct in the present case, for the portions of the truss AB and DE; since in finding the moment at C the loads on these portions of the truss are not redistributed. It has been shown (Article 8) that all influence lines for single loads between panel points are straight lines; therefore that portion of the influence-line which lies within the panel is then constructed by connecting J and E, the points of intersection of the influence-line already drawn, with the verticals erected at the panel ends. The influence line is then $EFJA$.

In order to find the position of a series of concentrated loads causing the maximum moment at the section C, it will manifestly be incorrect to use the criterion discussed in Article 14. A criterion for similar use is however easily deduced.

Art. 16. Criterion for Maximum Moment at any Section of a Truss.

The following notation (Fig. 12) will be employed:—

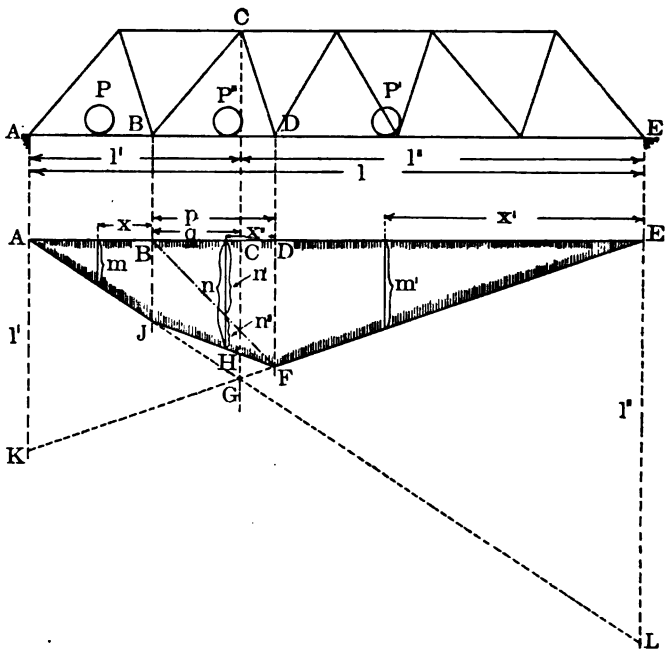


Fig. 12.

l' and l'' = the distances from the left and right abutments to the center of moments respectively;

l = the length of span;

p = the length of the panel;

q = the distance from the center of moments to the left end of the panel;

P and P' = any loads on the sections AB and DE respectively;

P'' = any load within the panel BD;

x, x' and x'' = the respective distances of P, P' and P'' from the right ends of the various sections:

m, q and n = the respective influence ordinates for P, P' and P''.

Then, as before, the moment M, for any position of the loads, becomes

$$M = \Sigma(P \cdot m) + \Sigma(P'' \cdot n) + \Sigma(P' \cdot m') \qquad \text{Eq. (1)}$$

If the ordinate n is divided into two parts n' and n'' by the line BF, then the moment M, for any position of the loads, using a notation similar to that before, becomes

$$M = \Sigma(P \cdot m) + \Sigma(P \cdot {}''n') + \Sigma(P \cdot {}''n'') + \Sigma(P \cdot {}'m') \qquad \text{Eq. (2)}$$

Eq. (1) may take the following form, by substituting for the influence ordinates, equivalent values found from the similar triangles of Fig. 12:

$$M = \Sigma\left[P \cdot BJ\frac{(AB - x)}{AB}\right] + \Sigma\left[P'' \cdot \frac{DF(BD - x'')}{BD}\right] + \Sigma\left[P'' \cdot \frac{BJ \cdot x''}{BD}\right] + \Sigma\left[P' \cdot \frac{DF \cdot x'}{ED}\right] \qquad \text{Eq. (3)}$$

If the loads advance a distance Δx to the right, the change in the values of the moment become ΔM and is equal to:

$$\Delta M = \Sigma\left[P \cdot \frac{BJ \cdot \Delta x}{AB}\right] + \Sigma\left[P'' \frac{DF \cdot \Delta x}{BD}\right] - \Sigma\left[P'' \cdot \frac{BJ \cdot \Delta x}{BD}\right] - \Sigma\left[P' \cdot \frac{DF \cdot \Delta x}{ED}\right]$$

$$= \Sigma\left[P \cdot \frac{l''}{l} \cdot \Delta x\right] + \Sigma\left[\frac{P'}{p} \cdot \frac{l''(l'' + q - p)\Delta x}{l}\right] - \Sigma\left[\frac{P''}{p} \cdot \frac{l''(l' - q)\Delta x}{l}\right] - \Sigma\left[P' \cdot \frac{l'}{l} \cdot \Delta x\right]$$

$$= \Sigma\left[P \cdot \frac{l'}{l} \Delta x\right] + \Sigma\left[\frac{P''}{pl}(ql - l'p)\Delta x\right] - \Sigma\left[P' \frac{l'}{l} \Delta x\right]$$

For a maximum or minimum $\Delta M = 0$; noting that

$$\Sigma\left[P\frac{l''}{l}\right] = \Sigma\left[P \cdot \frac{l}{l}\right] - \Sigma\left[P\frac{l'}{l}\right],$$

there is found:

$$\Sigma P - \Sigma\left[(P + P' + P')\frac{l'}{l}\right] + \Sigma\left[P'\frac{q}{p}\right] = 0 \qquad \text{Eq. (4)}$$

If ΣW represent all the loading on the span, then Eq. (3) will take the form:

$$\cdots \Sigma P + \frac{q}{p} \Sigma P'' = \frac{l'}{l} \Sigma W \qquad \text{Eq. (5)}$$

This criterion is used in the same manner as the criterion deduced for finding maximum moments in a simple beam; it differs from it in this respect, that the left-hand member of the equation does not include the sum of all the weights situated to the left of the center of moments, but only a definite portion; it will usually be found that the conditions of the equation are fulfilled by placing a wheel load at the left end of the panel.

Art. 17. Variation of Moment Within a Panel for a Fixed Position of the Loading.

Before proceeding with an example showing the application of the criterion just deduced, it will be advisable to show that, if a series of concentrated loads is fixed in position on a truss, the variation of the bending moment between panel points may always be represented by a straight line. Let it be required to find the variation of bending moment in the panel p of the truss shown in Fig. 13, the position of the wheel loads being fixed. Let R be

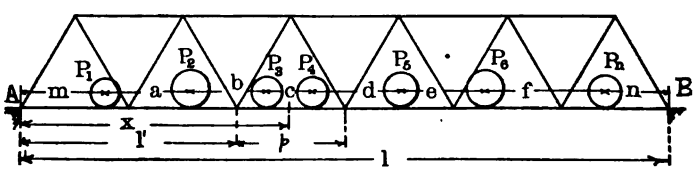


Fig. 13.

the reaction at the left end of the truss for all the loads shown on the truss, and R_1 the reaction at the left end of the panel CD, for the loads within the panel; the other notation to be employed is shown in the figure. Then

$$R = P_1(a + b + c \cdots n) + P_2(b + c + d \cdots n) \cdots + P_n \cdot n \cdots$$

$R_1 = P_3(c + n') + P_4(n') \cdots$, n' being the distance between P_4 and the left end of the panel.

If M represents the moment at any point in the panel p distant x from A:

$$M = R \cdot x - P_1(x - m) - P_2(x - a - m) \cdots - R_1(x - l') \quad \text{Eq. (1)}$$

Eq. (1) shows that between panel points M varies directly as the first power of x and that the variation may consequently be represented by a straight line. Therefore, to find the moment at any section within a panel, for a fixed position of the loading, it suffices to know the moments at the panel ends; by connecting the ends of the ordinates representing these end-moments by a straight line, any intermediate moment is easily obtained. This method is easily adapted for use with a funicular polygon, since the latter is a moment polygon for parallel loads.

ART. 18. PROBLEM IN FINDING MAXIMUM STRESS IN LOADED CHORD MEMBER OF A TRUSS WITH WEB MEMBERS ALL INCLINED.

An application in the use of the principles of the preceding articles will be made in finding the maximum stress in the loaded chord member 3–4 of the 6-panel deck truss shown in Fig. 14. The following data are required:

Panel lengths, all equal,	29 feet.
Length of truss,	174 feet.
Depth of truss at panel point a,	19 feet.
Depth of truss at panel point b,	24 feet.
Depth of truss at panel point c,	25 feet.

Locomotive loading: E 40. Cooper's Specifications.

The reaction influence line $LMNPQ\cdots$ and the stepped diagram $LABCDE\cdots$ are drawn in the usual manner; the truss itself is redrawn on a separate strip of paper, but in the reverse position to that of the upper diagram; the reason for this has already been explained (Art. 5); it is shown in dotted lines in the lower part of Fig. 14. This strip of paper must then be placed in such a position that the criterion of Art. 16,

$$\Sigma P + \frac{q}{p}\Sigma P'' = \frac{l''}{l}\Sigma W,$$

may hold with respect to the member 3–4.

In this case, q is the distance 3 to c'.
p " " " 3 to 4.
l' " " " 1 to c'.
l " " " 1 to 7.

Wheel 8 will rest at panel point 3 if the truss be placed in the position shown in the lower part of the figure. Verticals erected

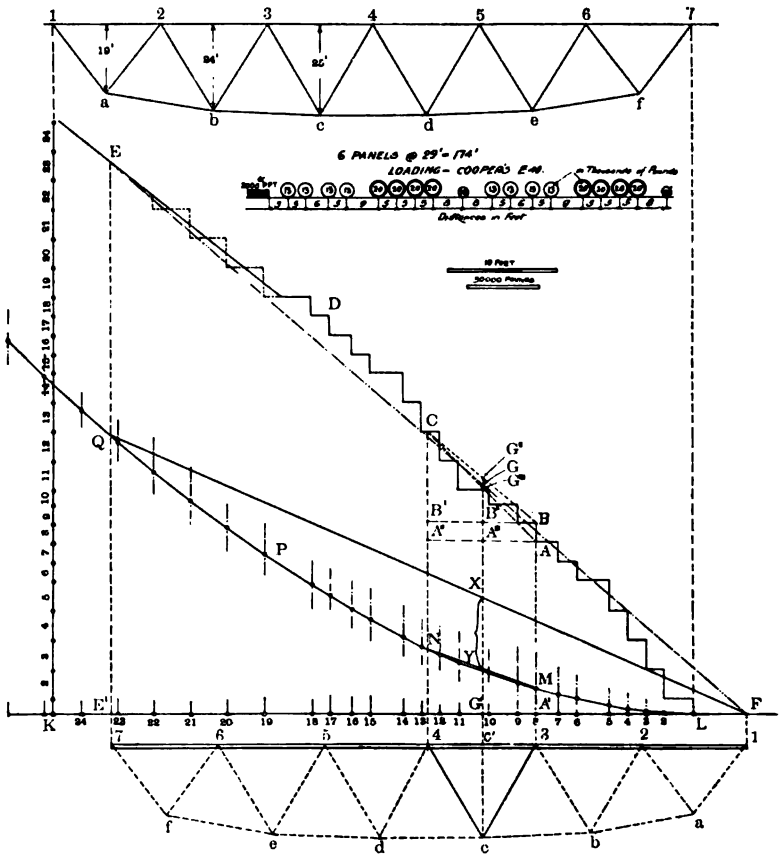


FIG. 14.

at the ends of the truss and at the panel points, 3 and 4, will intersect the stepped diagram at the points F, E, A and C respectively.

$\Sigma W'$ is then represented graphically by EE' and ΣP either by $A'A$ or $A'B$, since wheel 8 may be taken to act either to the right

or left of the panel point; for a similar reason, $\Sigma P''$ may be represented at corresponding times either by $A''C$ or $B'C$. From similar triangles,

$$GG' : EE' :: LG' : LE';$$

that is

$$GG' = \frac{l''}{l} \Sigma W.$$

According to the conditions of the criterion, GG' must equal either

$$A'A + \frac{q}{p} A''C$$

or

$$A'B + \frac{q}{p} C.B$$

From similar triangles it is seen that

$\frac{q}{p} A''C$ equals $A'''G'''$ and that $\frac{q}{p} B'C$ equals $B''G''$.

Therefore, by substituting these values in the criterion, the value of $G'G$ should equal either $G'G'''$ or $G'G''$. In the present case $G'G$ lies between these two values; it is evident that if wheel 8 be divided into proper parts at the panel point, the conditions of the criterion will be exactly fulfilled. In practice therefore it is only necessary to determine whether the point G lies between the lines BC and AC; if it does, as in the present case, this position of the loading will furnish one maximum value for the stress in 3–4.

It will usually be found that more than one position of the loading will fulfill the required conditions; in such a case, the actual values of the stresses must be determined, and the absolute maximum taken.

The value of the moment at C is found by means of the method of the preceding article. The closing line FQ of the funicular polygon is drawn and the points M and N, corresponding to the panel points 3 and 4, are connected by a straight line; the intercept XY when multiplied by the proper pole distance will give the value of the moment; in this case 8,352,000 foot-pounds. The stress in 3–4 is this moment divided by the lever arm cc'; that is $\frac{8352000}{25} = 334{,}100$ pounds compression. The stresses in the other

members of the loaded chord will then be found in precisely a similar manner.

ART. 19. TRUSSES WITH SUBDIVIDED PANELS.

Trusses of long spans frequently have panels subdivided in the manner shown in Fig. 15; in the case there shown the panel L_3L_5

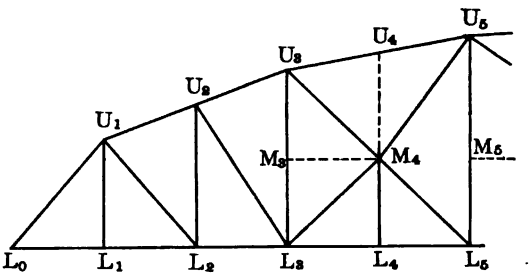


FIG. 15.

is divided by the tie rod M_4L_4, which is hung from the point M_4 and which distributes the weight it carries at its lower end to the main panel points of the truss, by means of one of several subsidiary trussed panels. In this way, long stringers and consequently heavy floor systems are avoided; the stresses in the truss remain perfectly determinate, but the criteria previously deduced either need some additional explanations or require some modification to be applicable to this form of truss. It should be noted that U_3L_5 is the main web member of the panel L_3L_5 and that U_5L_3 is the counter member; but that portions of each of these web members are also included in the subordinate framing. The members M_3M_4, U_4M_4, etc., shown in dotted lines are not true parts of the truss; their functions are simply to support compression members at intermediate points, and thus by reducing their effective lengths, permit the use of higher intensities of stress.

In the treatment which follows it will not be necessary to discuss both the main and counter web members, since the same methods are applicable to both; it is only necessary to remember that main members have their maximum stresses when the loading covers the longer portion of the truss and counter members when the loading covers the shorter portion of a truss.

Considering then only the panel L_3L_5, Figs. 16 to 19, illustrate by the dotted lines the various ways in which the subordinate brac-

ing may act to transfer the load brought to the point M_4 to the panel points L_3, L_5, U_3 and U_5. In Fig. 16 the trussing $L_3M_4L_5$ distributes the load to L_3 and L_5; in Fig. 17 the trussing $U_3M_4U_5$ distributes the load to U_3 and U_5; in the former case, the subordinate bracing (shown in dotted lines) is in compression; in the latter in tension. In Fig. 18, the trussing $U_3M_4L_3$ distributes the load to

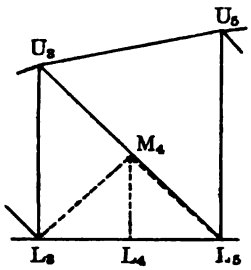


FIG. 16.

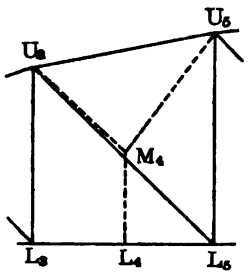


FIG. 17.

U_3 and L_3 and similarly in Fig. 19, $U_5M_4L_5$ distributes the load to U_5 and L_5; in these two cases the subordinate bracing is partly in tension and partly in compression; the tie-rod is however in all cases in tension.

ART. 20. MAXIMUM WEB STRESSES IN TRUSSES WITH SUBDIVIDED PANELS.

In the treatment for the maximum stress in U_3L_5 in the cases shown in Figs. 16 and 17, it will be at once seen that the bracing shown in dotted lines transforms the short stringers L_3L_4 and L_4L_5 into one trussed stringer, and that the loads on the panel length L_3L_5 are distributed only to the points L_3 and L_5. The criterion of Art. 12 may then be immediately applied, just as it stands, taking as the panel length, however, the length L_3L_5. The maximum stress in U_3L_5 will then be found as the tension resulting from the position of the loading determined by this criterion; but in Fig. 16 this stress must be decreased for M_4L_5 by that amount of compression which this portion of U_3L_5 carries as a member of the trussed stringer; similarly in Fig. 17 the stress in U_3M_4 must be increased by that amount of tension which this member carries as its share of the trussed stringer.

In considering the stress in the web member of Fig. 18, it will be necessary to consider the form of the influence line for stress

in M_4L_5. Passing a section through U_3U_5, M_4L_5 and L_4L_5, it is at once seen that for a load between the right abutment and L_5, the stress in M_4L_5 varies directly as the left-hand reaction; similarly for a load between the left abutment and L_4 the stress varies directly as the right-hand reaction. Consequently, the criterion of Art. 12 is directly applicable to M_4L_5, the panel length in this case being the short panel L_4L_5. This reasoning applies in exactly the same way to the short panel length L_3L_4 in the case of U_3M_4 of Fig. 19.

The maximum stress in the remaining portion of the member U_3L_5 in either of these two cases is then assumed to be the stress in that portion whose stress has already been determined, increased or diminished, as the case may be, by that amount of stress which the portion shown in dotted lines must carry in performing its duty as a part of the subordinate bracing. It is evident, however, that this result does not give the absolute maximum stress that may occur in U_3M_4 (Fig. 18) or M_4L_5 (Fig. 19). The stress in

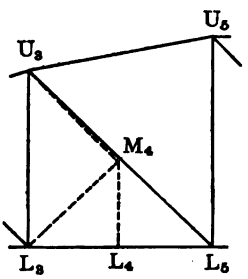


FIG. 18.

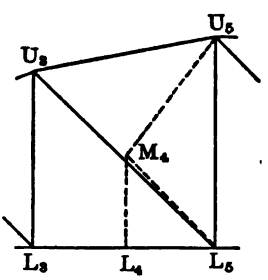


FIG. 19.

these members is composed of two parts; that part due to the true stress in the web member itself, and that part due simply to the weight carried by the tie rod. A criterion indicating the position of the loading giving a simultaneous maximum condition of these two factors is not a simple one; since but a small error is involved in assuming that the position of the load causing maximum stress in one portion of the web member will also cause the maximum stress in another part, the same position of the loading is generally assumed for both portions of the web member.

These investigations indicate that the maximum web stresses in trusses with subdivided panels may be obtained by means of methods previously deduced.

ART. 21. MAXIMUM CHORD STRESSES IN TRUSSES WITH SUBDIVIDED PANELS.

UNLOADED CHORD.

The stress in any unloaded chord member such as U_3U_4 (Fig. 20) is found by passing a section through U_3U_4, U_3M_4 and L_3L_4,

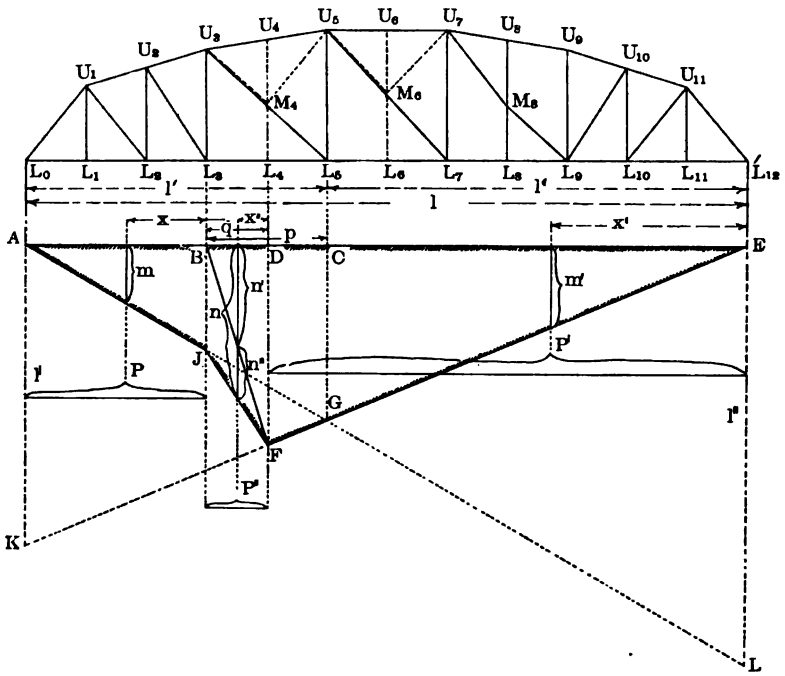


FIG. 20.

and with the center of moments at L_5, equating the moment of the external forces situated on one side of the section with the moment due to the chord stress. Although the center of moments is at L_5, the only external panel forces on one side of the section are L_1 to L_3; the load at panel point L_4 is not included.

This invalidates therefore the use of the simple criterion

$$\frac{W'}{W} = \frac{l'}{l}$$

deduced in Art. 14. By methods, parallel to those of that Article, however, the proper criterion may be quickly deduced.

The influence line for the stress in U_3U_4 is easily drawn, for as a load passes from the left end of the truss to panel point L_3, the stress varies directly as the right hand truss reaction, or as a straight line; a proper slope for this line may be indicated (as in the case of moments, Art. 13) by laying off EL equal to l'' on the left end of the reference line and connecting L with A, the right end of the reference line.

In a similar manner, the line EF indicates that between L_0 and L_4 the stress also varies as a straight line, and its slope is found by laying off AK equal to l, at the left end of the reference line.

Since all influence lines for single loads are straight lines between panel points, the influence line may then be closed by the line JF.

The notation which will be employed to develop the criterion is indicated in the figure; P, P'' and P' represent in general any load between L_0 and L_3, L_3 and L_4, and L_4 and L_{12} respectively, while m, n and m' represent the corresponding influence ordinates.

In general, then, the stress in U_3U_4 may be represented by the following expression:

$$S = \Sigma (P \cdot m) + \Sigma (P'' \cdot n) + \Sigma (P' \cdot m') \qquad \text{Eq. (1)}$$

The ordinate n may be divided by the line BF; then

$$\Sigma (P'' \cdot n) = \Sigma (P'' \cdot n') + \Sigma (P'' \cdot n'') \qquad \text{Eq. (2)}$$

By substituting this value of $\Sigma(P'' \cdot n)$ in Eq. (1) and by replacing the values of the influence ordinates by equivalent values found from similar triangles, the value of S becomes

$$S = \Sigma \left[P \cdot \frac{BJ(AB - x)}{AB} \right] + \Sigma \left[P'' \cdot \frac{DF(q - x'')}{q} \right] + \Sigma \left[P'' \cdot \frac{BJ \cdot x''}{q} \right] + \Sigma \left[P' \cdot \frac{CG \cdot x'}{CE} \right] \qquad \text{Eq. (3)}$$

By moving the loads an infinitesimal amount to the left the change in the stress or ΔS becomes:

$$\Delta S = \Sigma \left[P \cdot \frac{BJ \cdot \Delta x}{AB} \right] + \Sigma \left[P'' \cdot \frac{DF \cdot \Delta x}{q} \right] - \Sigma \left[P'' \cdot \frac{BJ \cdot \Delta x}{q} \right] - \Sigma \left[P' \cdot \frac{CG \cdot \Delta x}{CE} \right]$$

$$= \Sigma\left[P \cdot \frac{l''}{l} \cdot \Delta x\right] + \Sigma\left[P' \cdot \frac{l'' + p - q}{lq} \cdot \Delta x\right]$$

$$- \Sigma\left[P' \cdot \frac{l''(l'-p)}{l \cdot q} \Delta x\right] - \Sigma\left[P' \cdot \frac{l'}{l} \cdot \Delta x\right] \cdots \text{Eq. (4)}$$

The condition for maximum stress requires that ΔS be placed equal to zero. By simplifying terms, and by noting that

$$\Sigma\left(P \frac{l''}{l}\right) = \Sigma\left(P \cdot \frac{l}{l}\right) - \Sigma\left(P \cdot \frac{l'}{l}\right)$$

there will be found that

$$\Sigma\left[(P + P' + P') \cdot \frac{l''}{l}\right] = \Sigma(P) + \Sigma\left(P' \cdot \frac{p}{q}\right) \qquad \text{Eq. (5)}$$

Eq. 5 is similar in form to Eq. 5 of Article 16, desired for the maximum bending moment at any point in a simple truss. It differs however in this essential that in the present case the factor to be applied to the loads within the panel is p/q and not q/p.

The position of the loading having been determined by means of this criterion, the stress in U_3U_4 is found by taking moments about L_5. The maximum stress in U_4U_5 occurs with the same position of loading as U_3U_4, and its value is also the same.

Loaded Chord.

The stress in any loaded chord member such as L_3L_4 is found by passing a section through U_3U_4, U_3M_4 and L_3L_4, and taking the center of moments at U_3. This permits the use of the simple moment criterion

$$\frac{W'}{W} = \frac{l'}{l}$$

of Art. 14, and no unusual conditions are encountered in finding the stress in L_3L_4. The maximum stress in L_4L_5 is found with the same position of loading as L_3L_4, and the value of its stress is exactly the same.

THE GEOLOGY OF THE CERRILLOS HILLS, NEW MEXICO.

By DOUGLAS WILSON JOHNSON.

PART I. GENERAL GEOLOGY.

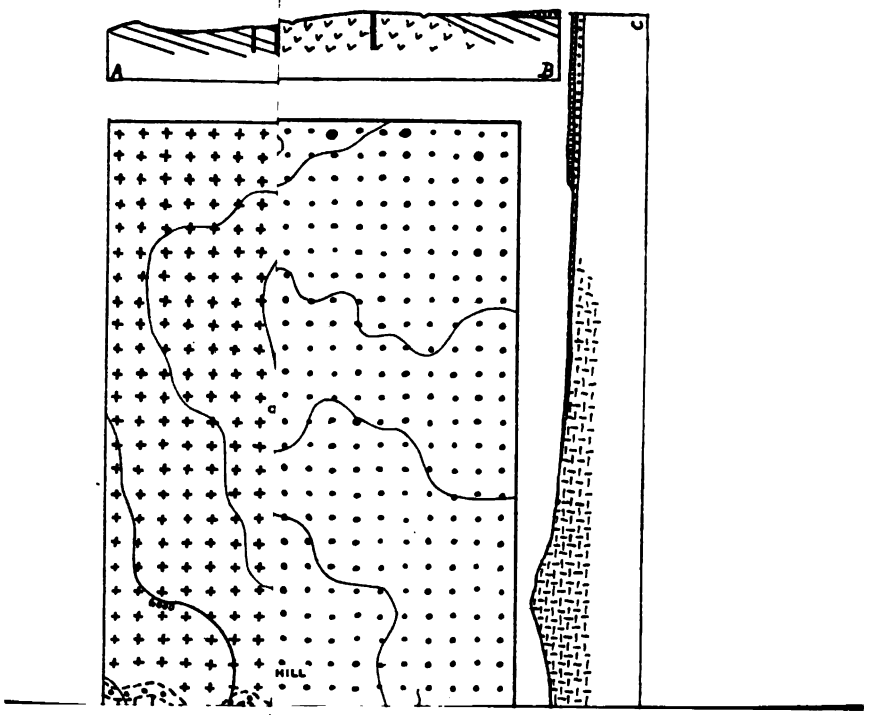
(*Continued.*)

Areal Geology.

On the geological map accompanying this report I have endeavored to represent the areal geology with as fair a degree of accuracy as the nature of the base maps would permit. As previously stated, the topography indicated by the contour lines does not accurately represent the relations of the true topography to the geology. It will be seen however, that the Santa Fé Marls occupy a large portion of the area north and south of the Galisteo Creek, while the underlying Cretaceous beds are exposed only where the creek and its tributary arroyos have removed these marls. West of the hills there is a broad, open vale where the marls have been stripped off almost entirely, giving the most extensive exposures of the Cretaceous in the region.

Except where the laccolithic intrusions of the Cerrillos Hills have disturbed them, the beds older than the Santa Fé Marls all dip uniformly to the east at an angle of from 15 to 20 degrees. Thus in passing from the western edge of the area to the eastern limit, we have a geological section beginning with the top of the Jura Triassic (?) red beds at the base, and passing up through the Cretaceous to the upper portion of the red sandstones of the Galisteo Group (Larimie?). Unfortunately, this section is greatly broken along the Galisteo Creek, where the best exposures are to be found, by the laccolithic intrusions of the Cerrillos Hills. Farther to the south, where the beds are less disturbed, the horizontal covering of Santa Fé Marls conceals them, and exposures are only found in the valleys and arroyos.

The movement which produced this uniform eastward dip was probably the same which resulted in the great monoclinal uplift of the Sandia Mountains some thirty miles to the southwest. Throughout the whole region east and west of the Sandia range,


A
B
C
HILL

for thirty miles or more in either direction, there is a notably uniform dip to the eastward, except where local uplifts have affected the sediments in their immediate vicinities. To the south this uplift is pronounced in the Manzano and more southern ranges, which are continuations of the Sandia range. For this great movement I propose the name of "Sandia uplift." It has been noted by some of the earlier geological explorers and in the geological section from the Mississippi River to the Pacific Ocean, prepared by Wm. P. Blake from the notes of Jules Marcou,* it is represented as culminating in the Sandia Mountains.

This uplift has resulted in a series of great north and south fractures. Twenty-five miles west of the Sandias the Cretaceous is faulted up against later beds along a north-and-south break which was traced for thirty or forty miles. Nearer the range, a series of recent volcanic cones occurs along a north-and-south line, doubtless marking an extensive north-and-south fracture. The Sandias themselves, together with their southern extensions, mark a great north-and-south fault which had a throw of over four thousand feet in places. Less conspicuous, but quite extensive north-and-south faults occur at other points throughout the general region.

In view of the above facts it is interesting to note that the groups of laccolithic mountains of which the Cerrillos Hills form the northernmost member, are arranged along a nearly north-and-south line. The rocks composing them are of the same general character, as shown by the study of thin sections, while their mode of occurrence is similar. It seems not unlikely, then, that the Cerrillos, Ortiz, San Pedro and South Mountains occur along one of the great north-and-south fractures, which fractures served to release the andesitic lava confined below. The fracture died out before reaching the surface, so that the rising molten lava spread laterally, and arched up the overlying beds, forming great laccolithic intrusions. In each case the overarching beds have been largely removed, but the highly inclined strata around the intrusive reveal the nature of the uplift. For convenience I shall speak of the several laccolithic intrusions forming the Cerrillos Hills as the "Cerrillos intrusion."

With this understanding of the two main movements which have materially affected the position of the sediments, we can trace

* Pacific Railroad Reports, Vol. III., Plate.

out the areal distribution of the beds more intelligently. If, then, we start at the western edge of the sheet and follow southeastward up the valley of the Galisteo Creek, we begin with the easterly-dipping red sandstones and shales of the Jura-Triassic (?) series (Fig. 7). We soon reach the limit of this series and encounter the yellow and white sandstones referred doubtfully to the Dakota group of the Cretaceous. A short distance still farther east are dark shales of undoubted Colorado age. From here to the western edge of the Cerrillos Hills, a distance of two miles, perhaps, the whole area is occupied by dark shales and thin beds of sandstones, which have been tilted and faulted by the Cerrillos uplift. Fort Pierre fossils were found at several localities throughout this area. Along the western base of the hills the beds dip westward, away from the uplift (Fig. 6), but farther south the eastward dip continues.

As we pass on eastward along the southern base of the hills, we find that here the beds dip sharply to the south, away from the uplift, while further south the eastward dip remains unchanged. The beds are of Fort Pierre age. Close to the base of the hills Fort Benton strata are brought up to view by the laccolith, while farther south Fox Hills beds are encountered.

Farther eastward we pass up into strata of the Madrid Group, of Fox Hills age. These beds are well exposed in Ortiz Arroyo, and further south as far west as Madrid and Rogers, where they dip a little north of east, and contain the coal seams of economic importance. A mile east of Cerrillos they are turned up vertical by one of the smaller laccolithic masses, and then dip more gradually eastward as we pass away from the uplift (Plate G and Fig. 4).

East of the Madrid Group we find the red sandstones of the Galisteo Group, of Laramie (?) age, which have the usual easterly dip except on the north side of the creek near the intrusives, where in places they are turned up quite sharply. Eastward, however, where the "petrified forest" is found, the effect of the Cerrillos intrusion has died out entirely, and the dip to the east is quite uniform throughout the whole area (Fig. 4). Under the influence of the intrusion the contact of this Galisteo Group with the underlying Madrid Group swings sharply eastward from a point just southeast of the town of Cerrillos, so that the red sandstones are found much farther west on the south side of the creek than on the north. The same is true of the Madrid Group, which is found as far west as Rogers on the south side.

CRATER HILL. (Low basalt crater northwest of the Cerrillos Hills.)

The ideal section, Fig. 8, shows the conditions above referred to, with all minor disturbances of the beds ignored. The actual sections, given in connection with the map, represent the conditions more accurately, as found in two representative sections across the area.

To recapitulate: The Jura-Triassic (?) and Cretaceous beds, exposed over the central and southern portions of the map, dip eastward under the influence of the great Sandia uplift, but are tilted in all directions close to the Cerrillos Hills under the influence of the local Cerrillos intrusions. The horizontal deposits of the Santa Fé Marls cover the northern and southern portions of the map, where they have not been eroded by the Galisteo Creek and its tributaries. It is to be noted that remnants of these Marls still remain, capping little mesas out in the valleys which the streams have carved. They are also found as little ledges adhering to the sides of arroyos carved in the hard rock of the Cerrillos Hills, in exposures extremely numerous, but too small to appear on the map.

The Cerrillos Hills themselves are shown on the map to occupy a somewhat central position in the area, their low, rolling foothills extending some distance east of the main peaks. These peaks, as well as the whole western portion of the intrusion, consists of rocks of the augite-andesite series, the several phases of which are discussed in Part III., Petrography. The low foothills to the east are of hornblende-andesite, this rock covering an area of two or three square miles. The smaller outlying hills to the northeast are of the augite-andesite rocks. In many places, both in the main hills and the smaller outliers, the andesite has been sheared and altered so that it appears white or yellow, in strong contrast with the dark gray of the fresh material. It is in these altered bands, which are quite extensive in places, that the turquoise deposits

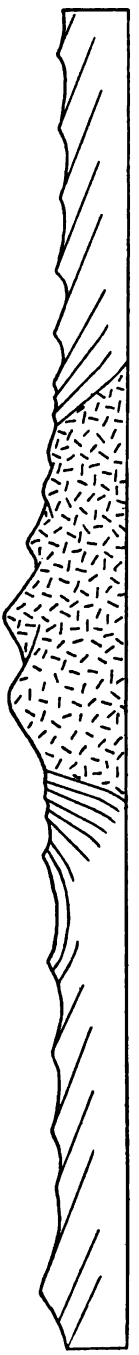


FIG. 8. Ideal east-and-west section through the Cerrillos Hills.

of Mt. Chalchihuitl and Turquoise Hill occur. Mineralized belts mark others of these sheared zones. A more detailed discussion of the hills is given inconnecti on with the consideration of their origin.

Northwest of the hills is the low basalt crater (Plate H) from which a thin flow of olivine basalt has spread out over the Santa Fé Marls (Plate F), covering several square miles of territory. The erosion which has exposed the Cretaceous in the low vale west of the hills has removed a little of the southern part of this basalt sheet, as well as the Marls immediately beneath it. The flow at this point is only 12 or 15 feet in thickness, and is notably vesicular. The rock is quite black in color, while near the crater it is a dull red, from abundant iron stain. It would seem that the surface of the Marls over which it flowed was fairly level, no marked unconformities of erosion being seen. The flow extends a little westward beyond the limits of the map, while to the north it merges with other similar flows, through which the Santa Fé Creek cuts its way. Northeast of the volcano the conical hill known as Mt. Calvary (Plate I) is shown on the northern edge of the map. This hill is composed of the feldspar free basalt, limburgite. Just east of it is another of the outlying hills of augite andesite.

At the western base of Mt. Calvary, and one mile east of Grand Central Mountain, are small exposures of the volcanic breccia which occurs interstratified with the red sandstones of the Galisteo Group, just east of the eastern border of the map (Plate J). At that point the breccia is shown to be over a hundred feet in thickness, with occasional lenses of red sand, indicating the intermittent action of the explosive volcano from which the material came. This breccia is well stratified, showing the effects of the sorting action of water. It rests on red sandstone containing silicified fragments of tree trunks. The petrographical discussion occurs in Part III. of this report.

In the southern part of the area are shown small areas of rocks of the hornblende-andesite series. These represent intruded sheets or sills of the andesite, which have their origin in the laccolithic Ortiz Mountains to the south, and dip east with the Cretaceous beds in which they occur (Fig. 5). Similar sills of the augite andesite are found at several places along the south and west sides of the hills, where they dip away from the uplift, together with the beds in which they occur.

Radiating outward from the Cerrillos Hills is a beautiful system of dykes, some of which extend across the country for several miles as high walls. These are best shown in the vale west of the hills, where they are cut by a later series of basalt dykes radiating from the volcano to the north. In Ortiz Arroyo, south of the town of Cerrillos, one of the andesite dykes (Fig. 9) is well exposed,

FIG. 9. Dyke south of Cerrillos.

standing as a narrow wall fifty feet or more above the valley floor. This dyke is faulted several feet in an east-and-west direction, allowing the arroyo to cut through the narrow gateway thus formed. The "Madrid dyke" (Fig. 10), running north and south through Coal Gulch, seems to come from the Ortiz rather than the Cerrillos Group, since it grows steadily narrower to the north, and finally disappears entirely. The andesite dykes never cut the Santa Fé Marls, being older than they. Several basalt dykes south of the hills have a trend which suggests for them another origin than the volcano, as noted in subsequent pages.

Several small exposures of interstratified sheets of mica andesite are found south and west of the hills. One of these occurs in the Galisteo Monocline, the easterly dipping beds near the western edge of the area. Immediately above it are fossiliferous shales of

Colorado age. Another of these sheets is shown northeast of Waldo, dipping sharply away from the laccolith with the shales in which it occurs. Farther east, north of Cerrillos, shales of Colorado (Fort Benton) age are found near the laccolith. A third exposure of the andesite occurs along the road two miles and a half northwest of Waldo, in dark shales similar to those found at the two other localities. The resemblance of the rock in all three cases suggests that they are parts of the same sheet, and hence that some portion of the Colorado shales are brought to the sur-

FIG. 10. "Madrid dyke" cutting sandstones of the Madrid Group, in Coal Gulch.

face at the point northwest of Waldo, in the vale where most of the shales are apparently of Fort Pierre age. The disturbed condition of the beds, and the nature of the country, prevent accurate stratigraphic determinations. As noted in the petrographic description of this mica andesite, it appears that the rock was vesicular, and was poured out as a surface flow over beds of Colorado age, being subsequently buried, greatly altered, and finally uptilted by the Sandia and Cerrillos uplifts along with the beds in which it occurs.

Near the top of the Galisteo Monocline there occurs a small intruded sheet of the augite andesite, which may be an offshoot from

MOUNT CALVARY. (Conical hill of basalt north of the Cerrillos Hills.)

one of the dykes. The rock of this sheet shows some peculiar mineralogical variations, as noted in Part III.

Having now briefly sketched the more salient features of the areal geology, a consideration of the nature of the Cerrillos intrusion is presented, after which the subsequent physiographic history of the region will be discussed. We will then be in a position to review the main events in the whole geologic history of the region, so far as available records make this possible.

Origin of the Cerrillos Hills.

The Cerrillos Hills have been considered by some geologists as remnants of great dykes, and by others as remnants of old volcanoes, from which the flow and more or less of the cone have been eroded. So far as I am aware a laccolithic origin has never been suggested. This is not surprising when we consider the comparative youth of the laccolithic idea, the obscure relations which the Cerrillos Hills present, and the fact that the work of the earlier geologists was necessarily in the nature of brief reconnoissances.

Since the classic work of Gilbert on the Henry Mountains, laccolithic mountains have been described from a number of localities in the West. The work of Cross, Weed and Pirsson, Jaggar and others has established the importance of this type of mountain form, and given us a good conception of its peculiar characteristics. The study of the Cerrillos Hills leaves little doubt as to their laccolithic origin, and in the following paragraphs I shall endeavor to point out the features which convinced me of their identity in structure with laccolithic intrusions elsewhere described.

As evidence of the intrusive nature of the Henry Mountains, Gilbert pointed out the following facts, which may be applied as tests to any uplift supposedly of laccolithic origin: (1) No fragments of the eruptive are found in the associated strata; (2) the eruptive is never vesicular or fragmental, as in surface flows; (3) the inclination of the strata at high angles proves that they were tilted subsequent to their deposition; (4) sheets cut across the strata, and so must be subsequent to their deposition; (5) contact phenomena occur in the beds above, as well as those below, the laccoliths. In addition to the above, we may note the following features which are also more especially characteristic of laccolithic intrusions: (1) The dipping away of the strata in all, or many, di-

rections from the intrusive. This may not occur on all sides of a laccolith, as pointed out in the case of several asymmetrical laccoliths which have been carefully studied; or the evidence may be wholly wanting as a result of advanced erosion; or, as is the case in parts of the Cerrillos region, it may be wholly obscured by being covered with later sediments. (2) The occurrence of intrusive sheets, especially thick near the laccolith, dipping away from it at more or less high angles, together with the strata in which they occur. These are the sheets which fill in the hollows of the bending strata near the base of the laccolith. Intrusive sheets may also occur in all other positions about the laccolith. (3) The presence of annular drainage (sometimes inherited in the hard rock of the laccolith itself). These features may be absent, but when present are valuable evidence in favor of a laccolithic origin.

In the Cerrillos region the laccolithic origin of the hills is not shown with the diagrammatic clearness that is found in some groups of similar origin. It is probable that the Sandia uplift occurred previous to the Cerrillos uplift, and that the laccolithic masses were intruded in the inclined strata. As has been shown by Cross and others, this results in more or less irregularity of form. It also appears from the evidence available that part of the Cerrillos laccoliths were intruded before the rest, which is another cause of irregularity in form. Erosion has removed all of the sediments from the hills and has greatly dissected the intrusive rock. Thus the evidence of over-arching sediments is lacking. At the same time, erosion has not cut deep enough to reveal good exposures of the base of the intrusives.

Subsequent to this erosion the great alluvial fans of the Santa Fé Marls spread out over the region and completely buried everything except the peaks of the hills themselves, wholly obscuring all traces of the upturned sediments and other evidences of the true nature of the uplift. More recent erosion has removed these marls from the southern base of the hills, but the whole northern portion still lies buried beneath this mantle, the conical peaks rising abruptly from the plain.

In view of these facts it is not strange that earlier geologists, giving to these hills but limited study, should regard them as remnants of great dykes or surface volcanoes. When studied in more detail, however, they offer the following evidences of their laccolithic origin:

1. In the case of the Cerrillos Hills, no fragments of the eruptive are found in the associated strata. This statement does not apply to the Santa Fé Marls, of course, which are of much more recent age, of alluvial origin, and which may therefore be ignored in this discussion.

2. In no case is the rock vesicular or fragmental. On the contrary it is a hard, dense rock, compactly crystalline, almost granitoid in places, and showing every evidence of having cooled in depth under pressure. (See Part III., Petrography, of this report, under the Hornblende-Andesite and Augite-Andesite Series.)

3. The strata dip away from the hills at high angles, thus proving tilting subsequent to deposition. In several places near the intrusive the beds are almost vertical, while east of Cerillos they are even pushed back beyond the vertical. (See Figs. 4 and 6 and Plate G. Also sections on map.)

4. In a few localities sheets were seen to send out tongues of the lava into the adjacent beds, thus proving their intrusive nature. One such case is well shown in Achavica Arroyo, west of Grand Central Mountain.

5. Contact phenomena were noted in the beds which rested upturned against the laccolith. Sandstones were hardened to quartzites, while shales and their contained fossils were profoundly metamorphosed. In places the shales were baked to very dense hornstone, as near the locality mentioned above.

6. Wherever exposed, the beds dip in all directions away from the laccolith. The only exceptions to this case are found in a few small exposures, which represent small blocks faulted into abnormal positions, or caught up in the mass of the intrusive itself. Apparent abnormal dips on the east side of the hills are shown to be due to small subordinate laccoliths. This dip away from the intrusive is best shown south of the hills, where the Galisteo Creek has cut the best section through the critical points. Here the strata in contact with the intrusive dip south at an angle of from 70° to 80°. On the south bank of the creek the dip changes to 65°, 50° and 40°, finally dying out until the beds resume their usual easterly dip.

7. Intrusive sheets, especially thick and dipping away at high angles near the uplift, thinner and less steeply inclined farther away are found in several localities throughout the region. Some of the best of these are shown along the creek between Cerrillos

and Waldo. Here one great sheet occurs in Cretaceous shales which dip 80° to the south, or away from the laccolith (see Plate K). The soft shales have been so greatly eroded from about it that it stands up like part of a huge east and west dyke. Just south are several thinner sheets, dipping at angles from 65° to 40°. The accompanying diagram (Fig. 11) will serve to illustrate the conditions there represented.

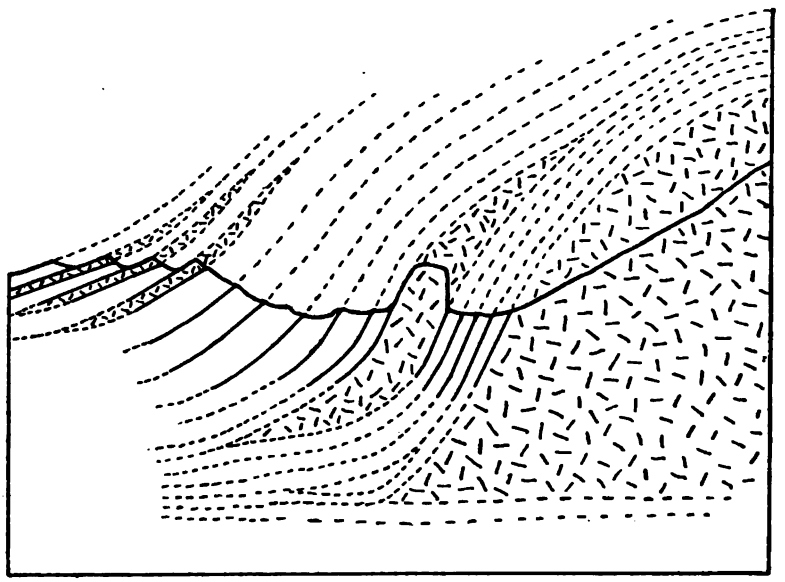


FIG. 11. Diagram illustrating relations of intrusive sheets west of Cerrillos.

Another such intruded sheet, similar to the larger one above described, is seen as a great wall east of Cerrillos. The shales are here nearly vertical. Smaller sheets of this nature are found in a number of places throughout the region. The large sheets of the Madrid area have their origin in the Ortiz Mountains, farther south, and occur in beds which have been but little disturbed from their easterly dip. It is possible that they have their origin in dykes, as is apparently the case with some small sheets in the area west of the hills.

8. There is some evidence of inheritance of annular drainage from valleys in previously domed sediments. San Marcos Arroyo follows around the eastern and southeastern side of the hills, and, as can be seen from the contour lines, is contin-

ued around toward the northwest in a low depression, to a point northeast of Turquoise Hill. From Cerrillos, where San Marcos Arroyo joins the Galisteo Creek, the drainage is to the northwest, while Achavica Arroyo, rising between two of the main laccoliths, flows down the western side of the hills. This drainage was established prior to the formation of the Santa Fé Marls, as shown in subsequent pages. A considerable portion of San Marcos Arroyo is in the hard rock of the laccolithic mass itself. And even where the arroyo seems to follow near the contact of the sediments and the laccolith, it has cut narrow gorges through offshoots of the main mass. Such a case of inherited drainage is shown in Fig. 12,

FIG. 12. San Marcos Arroyo. Gorge through narrow ridge of hornblende andesite.

where the arroyo cuts through a short, thick ridge of the andesite, although lower and more easily eroded country is found a few rods both north and south of the gorge.

The Cerrillos Hills present some obscure relations, but from the evidence just set forth the laccolithic origin of the hills is apparent. Regarding the exact number and relations of the several laccoliths I am in doubt. The following conditions seem to me most probable, although I am far from asserting them as certainly true.

The earliest intrusion was that of the hornblende andesite, which now forms the eastern foothills of the Cerrillos group. This andesite is cut by dykes of the later intrusive. In it are a number of inclusions of the upper Cretaceous sandstones (Madrid and Galisteo Groups), while near its western limit is found a small exposure of the volcanic breccia (Galisteo age), dipping off to the west. The western limit of this rock was difficult to determine, so closely does it resemble the later intrusion of augite andesite. The contact between the two, as shown on the map, is only approximately correct. This older laccolith sent off sheets into the surrounding beds, some of which are still well shown in San Marcos Arroyo. With it were several subordinate laccoliths, one of which is fairly well exposed east of Cerrillos. That it was asymmetrical is indicated by its abrupt southern face, near which the beds are vertical, while to the north it slopes more gradually, beds between it and San Marcos Arroyo dipping northward from it at a much lower angle. This subordinate laccolith is the only one in the group upon the top of which I found any sediments. On its northern slope were some thin sands and shales, not wholly eroded. At its base, also, I made out uncertain evidence of the underlying shales. It was intruded in the highest shale bed of the Madrid Group, as shown in Fig. 4, which represents the contact of these beds with the eastern side of the laccolith. Farther north, the beds in San Marcos Arroyo dip north, indicating the position of another of these smaller laccoliths. The Santa Fé Marls conceal the area just south.

Just what relation this intrusion bears to that of the augite-andesite series to the west, I am uncertain, but it seems most probable from the field relations that the later intrusive was injected west of the older laccolith, but spread eastward to join with it. It may, indeed, have enlarged that laccolith by insinuating itself between its top and the overlying beds, having since been more or less completely eroded. In this connection it is interesting to note that a little of the typical augite andesite was found in several places over the hornblende-andesite area, where it occurs in small exposures of a breccia largely of hornblendic fragments.

It seems probable, from the relation of the sediments near the head of Achavica Arroyo, that the main body of the hills is composed of two adjoining laccoliths, one embracing Santa Rosa, Santa Rosita, Lueras and Achavica Mountains, the other Mount

TWO VIEWS OF BEDS OF VOLCANIC BRECCIA INTERSTRATIFIED WITH SANDSTONES OF THE GALISTEO GROUP, EAST OF THE CERRILLOS HILLS.
(Showing stratified character of breccia.)

McKensie, Grand Central Mountain, and the whole of the southern foothills. From Lueras Hill a broad sheet or subordinate laccolith extends southwestward, capping beds which dip toward the east. The beds still farther west show a westerly dip, possibly indicating the position of another laccolith not yet exposed. The greater part of these laccolithic masses seem to be intruded in Fort Pierre shales. Near Cerrillos, however, Fort Benton shales occur, apparently as a small block faulted into an abnormal position. These shales dip in toward the hills, instead of away from them.

Of the outlying subordinate laccoliths Rocky Butte (Plate L), a mile or two to the northeast, is the only one near which the older sediments are exposed. Just east of it the red sandstones of the Galisteo Group are vertical and strike northeast and southwest. Columnar structure is well developed in this hill, the columns being vertical, and so proving that it is not merely the remnant of one of the radial dykes.

Gray Hill, Turquoise Hill (Plate O) and Bonanza Hill, to the northwest, are similar subordinate laccoliths, but are wholly surrounded by the horizontal beds of the Santa Fé Marls. Whether these have special conduits beneath them, such as dykes from the main hills, perhaps, or whether they represent local enlargements of sheets spreading out from those hills (bearing the same relation to them that the Mato Tepee does to the Little Missouri Buttes, according to Jaggar) can only be conjectured.

The symmetrical basalt cone, Mt. Calvary (Plate I), at the north, is surrounded by Santa Fé Marls except at its western base, where a little of the volcanic breccia found in the Galisteo Group is exposed. The facts that the rock is not vesicular, nor fragmental, but is hard and dense, and shows evidence of having cooled under pressure; that there is no evidence of any lava flow having ever been associated with it; and that the hill is so strikingly symmetrical, suggest that it is the remnant of an eroded laccolith. But this would necessitate the assumption that the ultra-basic limburgite composing this hill was intruded long before the related limburgites occurring in the more recent dykes, since such an intrusion must have occurred when there was a great mass of overlying sediments. While not impossible that we may have two rocks almost identical in all their characters, but of widely different age, it is nevertheless a questionable hypothesis. To regard this hill as the neck of an old volcano would necessitate the assumption that

the Santa Fé Marls were thicker here and an overlying crater and flow have been completely eroded, which seems most unlikely in view of the relations of the Marls to the other basalt flows in the region. If it represents merely a surface overflow from a dyke or other conduit, the petrographic features are certainly not what we would expect in a rock occurring in this manner.

The beautiful system of radial dykes is well exposed by the erosion of the softer beds in which they occur. Such a system of dykes has not been recorded in connection with any of the great type laccoliths of the west. The Crazy Mountains, where such dykes are most beautifully developed, are regarded as great "stocks," with only subordinate laccoliths associated, and the dykes radiate outward from the stocks. Dykes are mentioned from all of the laccolithic mountains described, but they occur above the laccoliths, below them, or scattered throughout the region, without any orderly arrangement. In the Cerrillos region, however, these dykes radiate outward from a common center, which is located toward the northern end of the hills. The low basaltic volcano to the northwest also marks a nucleus from which radial basalt dykes extend outward to intersect the older andesitic series. Several basalt dykes south and southeast of the hills have a trend which suggests their independence of the crater to the northwest. They may have come up from the reservoir below, along independent lines of fracture.

I do not believe that the radial dykes of the Cerillos region are due to radial fractures produced by the intrusion of the lava. Whatever the nature of the conduit, it was probably not of sufficient magnitude to produce the results noted. This would be especially true of the liquid basalt flow, the extrusion of which was so quiet as not to greatly disturb the horizontal Santa Fé Marls. The fact that these dykes were not contemporaneous with the greater masses is also attested by the notable difference in the rocks constituting the two. Were they the result of one intrusion, the rock in both should be the same. As a matter of fact the dyke rocks are more basic, as is so often the case. This is especially true in the case of the basalt, the flow being an ordinary olivine basalt with much plagioclase, but all of the dykes being composed of ultra-basic, feldspar-free limburgite. It is also found that the dykes cut the greater masses in places.

Pirsson has already offered a very plausible explanation of the phenomena of radial dykes of this type.* It is pointed out that when the surrounding beds lose the heat imparted to them by the eruptive mass, they will contract, producing cracks, which, if the beds be fairly homogeneous and undisturbed, will assume a more or less radial position. These cracks may then be filled with the lava from below, forming dykes which are of more recent age than the main masses. As a result of the continued differentiation of the magma in depth, such dykes are usually more basic than the earlier intrusives. It seems to me that such an explanation most readily accounts for the conditions which are found in the Cerrillos region.

It remains to note the evidence furnished by the position of these dykes regarding the relative ages of the Sandia uplift and Cerrillos intrusion. If the andesite were intruded in horizontal strata, the subsequent cooling and contraction would naturally develop vertical fissures. If the Sandia uplift then tilted the beds, the dykes which formed in these fissures would be tilted also. As a matter of fact the dykes generally appear to be quite vertical. The fact that only a few of the dykes approximately parallel to the strike of the beds are well exposed, as well as the possible complicating conditions which might destroy the original hypothetical simplicity, makes the evidence of only suggestive value.

General Physiography.

In the discussion of the origin of the Santa Fé Marls I have already considered the development of the great alluvial fans of the region, and the resulting topography. As was there explained, these Marls remain capping isolated mesas, or tongue-like ridges from the main body of the plains, where the Galisteo Creek and its tributary arroyos have not yet removed them. The main facts noted are these:

The Marls rest on the upturned edges of the Cretaceous beds. The contact shows a remarkably even horizontal plane truncating the easterly dipping sandstones and shales. Variations in hardness of the beds appear not to affect this plane, which, wherever exposed was uniformly even. The phenomena are essentially

* "Complementary Rocks and Radial Dikes," L. V. Pirsson. *Am. Jour. Sci.*, Vol. L., 1895, pp. 116–121.

those described by Gilbert as the results of "planation." * Exposures nearer the Ortiz Mountains indicate that this rock floor rises toward the ranges with a gentle slope.

The evidence would seem to indicate that subsequent to the Sandia and Cerrillos uplifts, and prior to the deposition of the Santa Fé Marls, the long-continued erosion of the first half of the Tertiary period reduced the region practically to a local peneplain, above which the several mountain ranges still projected as monadnocks.

I have called attention to the notable series of flat-topped hills along the Galisteo Creek and its arroyos, and which indicate the uniform level of the old alluvial plain, now being dissected. Much less noticeable is a second series of level platform-like elevations, about 75 or 100 feet lower than the former, and nearer the creek. These are also covered by the horizontal Santa Fé Marls which rest on the more or less evenly planed-off Cretaceous beds. We have thus two definite levels or terraces, each capped by the horizontal Marls. These two levels have been noted throughout the valley of the Rio Grande and its tributaries in many places. Hayden referred to a "double series of terraces" in a number of places in his report, as for instance, "The Rio Grande wears its way through these marls (Santa Fé Marls) with a bottom about two miles wide. On the west side are distinct terraces with the summits planed off smoothly like mesas. The first one is eighty feet above the river; the second one two hundred feet." †

As will be seen from the conditions in the Cerillos region, these terraces do not represent the type produced by a stream cutting out an old drift-filled valley. The terraces are cut in solid rock, and we apparently have a true case of terraces formed as a result of reëlevation of the region, allowing the streams to cut to a lower level than the floors of the old valleys in which they formerly flowed. In the bed of the Galisteo itself I have found traces of the old valley bottom, only seven feet above the present water level. Here, too, were remnants of the Santa Fé Marls capping the planed-off Cretaceous beds.

The Santa Fé Marls are found as mere remnants well up in every arroyo in the region. In the narrow gorges cut in the hard

* "Geol. of Henry Mts.," pp. 126–133.

† Prelim. Field Rep. U. S. Geol. Surv., Col. and New Mex., 1869, p. 69.

rock of the Cerrillos Hills the marls are represented by narrow ledges of the peculiar conglomerate still adhering to the sides of the valley walls, or still persisting in places in the beds of the arroyos. This shows that the drainage of the region was fully established in its present relations, previous to the formation of these marl beds. The influence exerted by the Cerrillos laccoliths in the establishing of this drainage has already been suggested.

The history of the drainage relations, if my interpretation of the phenomena is correct, is as follows: After the great Sandia uplift, tilting the strata to the east, and the Cerrillos intrusion, doming the beds in the central portion of the area, the early Tertiary erosion removed a vast thickness of beds and reduced the area about the mountains to a gently sloping plain. During this time the Cerrillos laccolithic intrusion and the domed beds above it went through the cycles of radial and annular drainage, a portion of the annular drainage being inherited in the hard rocks of the outer edges of parts of the intrusives. When the area was practically reduced, the slightly lower level marking the junction of the gentle slopes from the Ortiz and Cerrillos regions doubtless marked the location of an east-and-west stream. As a result of elevation this stream again became active, cutting a valley 75 or 100 feet deep into the plain, and then spreading laterally until the valley was widened out to a considerable breadth. A second elevation caused the stream to cut still deeper. In the meantime the more detailed drainage about the foothills of the Cerrillos group, which latter remained porjecting several hundred feet above the level of the plain, was established.

Now the conditions changed. From one in which erosion exceeded the supply of material, there was a change to a condition in which the supply was greatly in excess of the ability of the stream to remove. Torrential mountain floods washed great sheets of coarse débris out over the plain, and down into the terraced valley of the stream, giving the coarse conglomerates of angular andesite fragments which we find lying directly upon the rock floor to-day. These alluvial fans gradually buried the old plain-like level, the valley and the tributary arroyos, so that the old river bed must have been more than 100 feet below the level of the alluvial plain thus formed.

In time a condition of equilibrium was reached, then passed, and the stream began to remove the marls. Sufficient time elapsed,

however, for these marls to become quite compact in places before the valleys were again revealed, so that the lime-cemented conglomerate formed resistant beds which persist to-day, even in the beds of the streams as well as projecting ledges high up on the sides of arroyos from which all the rest of the Marls have been removed. This erosion is still being carried on, the old valleys being revealed, and cut still deeper. Near Waldo the present stream bed is several feet below the lowest level capped by the conglomerate, while toward the head of San Marcos Arroyo the Marls have not yet been cut through to the old stream bed.

General Geologic History.

As shown in the Sandia and other mountain ranges in this general region, the lowest beds represented are Upper Carboniferous limestones and sandstones which rest directly upon a floor of granite or ancient (Algonkian?) metamorphosed sediments. So far as the evidence shows, there is no stratigraphic unconformity from these Upper Carboniferous beds to the top of the Cretaceous, although such unconformity may exist and not be apparent.

Upon a floor of ancient crystallines, then, Upper Carboniferous limestones and sandstones were laid down. These were followed by the "Red Beds" of Permo-Triassic (?) age, consisting largely of massive and loose red sandstones, variegated marls and some beds of gypsum. Next came the sandstones and shales of Dakota (?) and Fort Benton Cretaceous age.

At this period volcanic activity developed, and flows of mica andesite were poured out over the Fort Benton shales. It is also possible that augite and hornblende andesites were represented in the eastern part of the area, in more massive development, as fragments of such rocks are found in later breccias.

The deposition of the Cretaceous sediments continued throughout the Fort Pierre epoch, shales being the prevailing deposit until toward the end of the Fort Pierre, when massive sandstone beds were laid down. At the beginning of the Fox Hills epoch the lignite beds of the Madrid Group were formed. Then followed the deposition of a thousand feet or more of yellow massive sands. These were followed by fifteen hundred feet or more of the red sandstones of the Galisteo Group. The land area was not far distant, and many tree trunks and branches were washed out over the sands and buried.

TOWN OF CERRILLOS AND SOUTHERN PART OF CERRILLOS HILLS. (Portion of great intrusive sheet shown at extreme left.)

Along this shore line a violently explosive volcano now became active, and the showers of rock, sand and ash which fell in the shallow water near the land were sorted by waves or currents, and so formed fairly well stratified deposits. The volcano blew out fragments of the old crystallines far below, as well as large and small masses of andesite from some old flow or intrusive. The activity ceased from to time, and lenses of the red sandstone formed before the next outburst. Finally the volcano became extinct, and more or less of the red sandstones formed above the volcanic breccias.

Now came the great Sandia uplift, tilting all of the beds to the east, and producing great north-and-south fractures and faults. Along one such line of weakness andesitic lavas rose to the level of the Cretaceous beds, and then spread laterally to form several groups of laccoliths, the most northern of which was the Cerrillos intrusion.* There were at least two or three stages of this intrusion, the earlier hornblende andesite of the Cerrillos Hills, for instance, having time to congeal before the augitic rocks were intruded. Intrusive sheets were formed contemporaneously with the laccoliths, and some of these sheets having their origin in the Ortiz intrusion farther south, spread out into the lower beds of the Madrid Group, several of them between the various beds of lignite.

The heat from the intrusive lavas spread through the associated sediments, producing profound metamorphism in places, and necessarily effecting a rearrangement due to expansion. The lignites of the Madrid area were gradually transformed to bituminous coal wherever the intrusive sheets were only separated from them by a hundred feet or so of shales. Where the sheets were nearer the lignite was transformed completely to anthracite, while in cases where the lignite was a considerable distance from the intrusive it remained unaltered. Some of these sheets cut through the lignite in passing from one horizon to another, and near the direct contact the carbonaceous bed was burned to a natural coke.

In course of time the intrusive and the surrounding sediments began to lose their heat, and contraction took place. As a result

* My reasons for regarding the Sandia uplift as prior to the Cerrillos intrusion are based mainly on the theoretical considerations brought out in the text. There seems to be corroborative evidence in the asymmetrical laccoliths, which cut lower formations to the west than to the east, and in the vertical position of the radial dykes. I know of no absolute proof as to which was first.

of this contraction more or less radial cracks were formed. Into these the molten magma was intruded from below, giving a beautiful series of radial dykes.

Meanwhile the erosive agencies far above were actively removing the overlying beds. Throughout the whole of the early Tertiary and probably up to the beginning of the Loup Fork period, this erosion continued. At last the laccoliths and their associated dykes were laid bare, maturely dissected, and the whole of the surrounding country reduced to a nearly level rock floor. Sheet-flood erosion was doubtless an important factor in this process of "planation." At this period a stream probably occupied a slight east-and-west depression between the Ortiz and Cerrillos Groups, being nearer to the smaller, or Cerrillos, Group. Remnants of the more or less annular drainage from the laccoliths doubtless persisted also.

Then came an elevation which permitted the east-and-west stream to cut a valley 75 or 100 feet deep in the old rock floor. Lateral corrosion widened this valley to a considerable extent when a second elevation allowed the stream to cut a second valley in the older valley floor. In this way two distinct terraces of solid rock were formed.

Great mountain torrents washed vast quantities of coarse, angular débris out over the surrounding country. The result was the formation of a conglomerate of angular fragments of the andesite, cemented by a calcareous cement, over nearly the entire area, relatively few places being left bare to be covered by the finer materials. As this conglomerate is found covering both series of terraces, and even the old beds of the streams, it is evident that the débris was able to fill up the old drainage valleys at once. Remnants of the conglomerate high up on the valley sides, and in the neighboring arroyos, show that the bottom of the lower valley of the main stream must have been buried under more than 100 feet of this débris.

The accumulation of this débris in the form of great alluvial fans continued, finer marls and sands soon predominating in the more distant portions of the fans, but frequently alternating with coarser, and even conglomeritic layers. By the lateral and distal confluence of these fans from the same and neighboring mountains, a great alluvial plain of the Santa Fé Marls was formed, sloping gradually from the mountains in all directions.

ROCKY BUTTE. [Columnar structure (columns vertical) well shown on eastern half of hill.]

At this time occurred the extrusion of the basalt northwest of the hills. The liquid lava flowed out over the marls from the low crater (Plate H) which still remains, in part. It is possible that this eruption developed the stresses which caused faulting of the andesitic dykes, which is quite noticeable over the whole area. Or both the faulting and the eruption may have resulted in part, at least, from the continued activity of the Sandia uplift. The latter would seem most probably the cause of the extensive shearing throughout the Hills, along lines striking a little east of north (see Plate P). More or less mineralization of these sheared zones occurred, and some true fissure veins were formed. Some of the sheared areas were profoundly altered, and turquoise formed among other secondary products. The heat from the eruption effected more or less expansion and rearrangement in the underlying beds. As this heat was lost, contraction produced radial cracks, which were then filled with an ultra-basic type of the basalt, giving basic radial dykes.

In the meantime the deposition of the Santa Fé Marls continued, and a part of the eastern edge of the basalt flow was buried under a thin cover of these deposits. Finally a condition of equilibrium was reached and then passed, when erosion began to exceed deposition of these fans. The main stream (Galisteo Creek) and its tributary arroyos soon revealed the old valleys, removing the looser marls, but leaving the resistant conglomerate, capping the series of terraces, and in places covering the stream beds. This activity worked headward along the streams, so that the marls are less completely removed toward the head of the Galisteo and the larger arroyos, while farther west the creek has cut several feet below the bottom of the old buried valley, and removed great quantities of the marls and soft Cretaceous shales. This erosion is still in progress, working toward a reëstablishment of the conditions which existed prior to the deposition of the Santa Fé Marls.

ECONOMIC GEOLOGY.

Coal.

From the economic standpoint, the most important product of the Cerrillos region is the coal of the Madrid field. The mines were operated in a small way for a number of years before the in-

dustry was put upon a firm basis in 1891. Since that time the anthracite and bituminous coal of this region have played an important part in southwestern markets, first under the control of the Atchison, Topeka and Santa Fé Railroad Company, and since 1899 under that of the Colorado Fuel and Iron Company.

At present three of the mines are being worked, on as many different seams. They are known as the Cerrillos Bituminous No. 27 (formerly Cook and White), the Cerrillos Anthracite A No. 28 (formerly Lucas), and the Cerrillos Anthracite B No. 33 (recently opened). The first of these mines is located at the town of Madrid, on a seam three and a half feet in thickness, and is opened by triple slopes driven downward along the easterly dip of 15 degrees, to a depth of 2,930 feet. An excellent quality of bituminous coal is produced. The Cerrillos Anthracite A No. 28 is located near the former, but on a seam some 200 feet higher. This seam is three feet thick, dips 15° east, and is opened by a slope 2,600 feet in depth. The best of true anthracite coal is produced. Just above this seam, and separated from it by only a few feet of sandstone, is one of the sills of andesite 130–160 feet thick. Above this easterly dipping sill, and separated from it by a thin stratum of sandstone, but half a mile east of Madrid and consequently at a lower altitude than the former mine, is a four-foot seam of good anthracite in which the Anthracite B No. 33 mine has been recently opened.

The total output of these mines, as given by the mine inspector, for the fiscal year ending June 30, 1901, was: bituminous coal, 75,295 tons; anthracite, 41,264 tons. The anthracite coal from both mines is screened and sorted in a large breaker near the northern end of the village. At Waldo are fifty bee-hive coke ovens where a portion of the product of the mines is reduced to coke.

The anthracite coal of this region has proven of special interest to the geologist, since in places it occurs in the same bed with bituminous coal, and was evidently produced by the metamorphic action of the intrusive. Associated with the coal are the intrusive sheets, or sills, already referred to, several of the radial dykes from the Ortiz and Cerrillos intrusive centers, while two or three miles farther south is the main mass of the Ortiz Mountains. Several theories have been advanced as to which of these three forms of eruptive was the active agent in effecting the transformation to anthracite. By a few the radial dykes which cut the coal, espe-

cially the big Madrid dyke which must have passed just along the present face of the main escarpment into which the mines were opened, have been regarded the true causes of the change. By most geologists the great sills which were intruded in the beds above and below the coal have been regarded as the efficient agents. This is the view which my own observation led me to

From *Camp and Plant.*

FIG. 13. Anthracite Breaker, Madrid.

adopt, and which is supported below. At first thought it might appear of value to give in detail the published opinions of those geologists who support this theory. So far as I am able to learn, however, their conclusions were based on no close study of the conditions, and so must be regarded rather in the light of suggestions. It may be said that the mine workers themselves believe in these sills as the sole agents in the transformation, and claim they can always foretell the close approach of the sheet by the variations in the coal.

Far more weight, however, must be given to the conclusions of Professor John J. Stevenson, who considers the main mass of the Ortiz intrusion farther south as the only effective agent in producing the transformation. So far as I am aware Professor Stevenson is the only one who has given any detailed study to this special

problem, and his excellent work, although necessarily limited to but a few days, can only command the most thoughtful consideration. In presenting my own views I shall accept Professor Stevenson's observations of phenomena as unquestionably correct, but endeavor to show how they will bear another interpretation, more in accord with certain theoretical considerations and some additional facts brought forward.

The main facts set forth in Professor Stevenson's discussion are as follows:

(*a*) In the upper one of the two main workable seams, known as the Lucas bed (same as White Ash bed), the coal toward the south, nearer the intrusive mass of the Ortiz Mountains, is all anthracite; at the extreme north of the workable area, farthest away from the intrusive mass, the coal in this same bed is largely bituminous; between the anthracite and bituminous is a broad area (3,000 feet along Coal Gulch) largely of soft, friable, "tender" coal which is unmarketable, but with some good anthracite in places.

(*b*) In the lower of these two main seams, known as the Cook and white bed, the coal farthest south, as indicated by fragments on dumps of old openings, is anthracite; the coal as found in the opening at the southern end of the village, directly under the "tender" coal of the seam above (which contains some anthracite even farther north) is a somewhat tender bituminous coal; the coal farther north was not well exposed, and no analyses were available.

(*c*) In the thin seams between the above two main beds, the coal farthest south, even two miles or more above the Lucas (anthracite) mine, is bituminous and shows no evidence of change.

(*d*) A drill hole west of Coal Gulch shows bituminous coal eight or ten feet above a sill 200 feet thick. The coal was not appreciably changed.

(*e*) The interval between the Lucas (White Ash) bed and the sill above it shows no great variations along the mesa front in Coal Gulch; "yet in the Lucas mine and all points examined south from it the coal is anthracite, whereas at all points north from it to the border of the eruptive rock one finds only transition coal."

(*f*) The coal was crushed into fragments, slickensided, and laminated.

Upon the above facts Professor Stevenson based the following conclusions:

"Mere proximity to a mass of eruptive rock is insufficient to produce any material change in the coal."

"Direct contact appears essential to change."

"The coal was changed into anthracite solely by contact of the beds with the enormous mass of eruptives" (two or three miles to the south).

"The coal was completely formed when the disturbance took place."

The facts above noted, upon which these conclusions are based, I accept without question. It does not appear to me, however, that the conclusions given necessarily follow. For instance, granting for the moment that the intrusive sheets, or sills, were the active agents, then:

(*a* and *b*, see above) If the intrusive sheets above and below the coal seams were very thick nearest the main mountain mass, but thin out and disappear to the north, or if they were nearer the coal at the south than at the north then we could conceive that the beds might be of anthracite toward the south, nearer the mountains, but bituminous farther north where the sheets were thinner and had less heat to yield for the metamorphic action, or where the sheets were farther away from the coal.

(*c*) The thin seams between the two main beds would then most naturally be of bituminous coal even far to the south, if not near such an intrusive sheet.

(*d*) It is conceivable that local cases of abnormally slight metamorphism might occur, in which lignite quite near an intrusive sheet would only be changed to bituminous instead of anthracite coal. Cases of such unequally distributed metamorphic action are so abundant in the literature of metamorphism as to need no detailed comment.

(*e*) As noted above (*a* and *b*), the occurrence of anthracite to the south and transition coal to the north, might be possible if the sheet thins out toward the north, regardless of minor variations in the distance of this sheet from the coal; while the fact that "at all points north from it (Lucas mine) to the border of the eruptive rock one finds only transition coal," whereas beyond the border of the eruptive we pass into bituminous coal, is exactly what we should expect on the basis of our assumption.

(*f*) If lignite were transformed by such sheets into bituminous coal and anthracite and then a later movement due to contraction, the intrusion of dykes or some other disturbance were to take place, we could get the crushing into fragments, slickensiding and

lamination, even though the coal was not completely formed when the first intrusion took place.

It is evident, then, that there is a possibility of placing an entirely different interpretation upon the facts noted by Professor Stevenson, provided that certain geological conditions are found in the area in question. As will appear, such conditions are found in the Cerrillos region; and they, in the light of several theoretical considerations and a number of facts to be noted, afford strong evidence in favor of the following conclusions:

The coal was probably in the form of lignite before the intrusion occurred.

This lignite was changed to bituminous and anthracite coal by the metamorphic action of the intrusive sheets or sills.

Mere proximity to these sills was sufficient to produce these changes.

Direct contact destroyed both the bituminous and anthracite coal without the production of anthracite from the former.

First, with regard to the geological conditions as found in the area:

The intruded sheets or sills are thicker toward the south, nearer the main eruptive mass. With an understanding of the laccolithic nature of the main intrusion, we would naturally expect these sills to grow progressively thinner as they pass farther and farther away from the parent mass. This is not always the case, local thickenings sometimes occurring; but as a rule it is true. The case in point, however, is no exception to the rule. Professor Stevenson has already referred to this thinning out of each of the two main sills toward the extreme north. (C. C. F., pp. 109, 115, 121.)* This northward thinning is equally marked farther south. A recent drill hole southeast of the town struck this second sill at the proper depth; after cutting into the sill for several hundred feet the hole was abandoned. Farther northwest, the thickness, as exposed a little north of the line of the Madrid section (Fig. 5), was seen to be over 250 feet. Northeast of here, on the mesa, Professor Stevenson noted (C. C. F., p. 108) that the thickness, as shown by a drill hole, was only 200 feet. Its continued thinning out and disappearance to the north he referred to elsewhere, as noted above. This variation in the thickness of the upper sill is

* This and the following similar references, refer to the pages of Professor Stevenson's paper on the "Cerrillos Coal Field," *Trans. N. Y. Acad. Sci.*, 1896.

less easily seen, owing to its having been subjected to long-continued erosion, but enough evidence remains to leave no doubt of its greater thickness to the south than to the north. The northward thinning has already been noted in the references to Professor Stevenson's paper.

Shearing and crushing subsequent to the intrusion of the sills has occurred. It has already been pointed out, in connection with the origin of the radial dykes found so beautifully developed about the Cerrillos and Ortiz laccoliths, that they probably represent a later intrusion than the laccoliths and sills. In any event, the evidence of profound shearing subsequent to the intrusion of these sills is abundant, and even the later dykes are badly faulted, whatever the cause may have been. Both laccoliths and sills are sheared and profoundly altered in places, and many faults occur.

It is evident, then, that we have in the Cerrillos region all of the conditions necessary to an explanation of the facts noted by Professor Stevenson on the basis of the theory here supported. So far as the phenomena observed by Professor Stevenson are concerned (with the exception of a few points, hereafter noted, which tend to contradict his theory) they are exactly what we must expect, whether they are the result of heat advancing northward from the main great igneous mass and crushing produced contemporaneously, or the result of heat radiating outward from northerly thinning sills and crushing produced subsequently. The question which now confronts us is this: Is there any additional evidence that will indicate which one of these two theories is correct?

Professor Stevenson records no fact in his discussion which is not readily explained as a natural result of metamorphism by northerly thinning intrusive sheets. The finding of practically unchanged bituminous coal only 8 or 10 feet above a sill 200 feet in thickness is considered evidence that direct contact is essential to change; but the question as to whether or not direct contact is essential is a minor one, and will be considered in subsequent pages. The main issue is with regard to the transforming agent itself — just how it is effective is an important but subsidiary consideration, and will be treated in its proper place. Professor Stevenson does record a few points, however, which seem to me to offer strong evidence in favor of the sill theory, and these will be taken up in detail below. In addition to the facts which offer no determinative evidence either way, and the few points just re-

ferred to which seem to me to favor the sill theory, there are several theoretical considerations, and a number of additional facts of field evidence, which seem to point strongly to the intrusive sheets or sills as the active metamorphic agent — or, in other words, that the heat which transformed the coal came downward and upward from the overlying and underlying sills, rather than horizontally along the coal bed itself.

As the least important among these considerations may be mentioned the fact that it is not shown that the coal was ever cut by the main mass of the intrusion to the south. Professor Stevenson has assumed throughout that the great igneous mass of the Ortiz Mountains did cut the coal beds. It does not seem to me that this is necessarily the case, however. Since the intrusive is probably in the nature of a great laccolithic mass, it is quite possible that the coal beds were arched up over the laccolith which was intruded at a lower horizon. According to Jaggar the sills are most frequently fed by limited conduits from the main laccolith, such as dykes, so that the coal strata need only have been cut by some such limited form of the intrusive. Hence we may entertain some doubt as to whether the efficient cause, assumed by Professor Stevenson, ever existed.

But if we were to grant that the assumption were correct, and that the enormous mass of eruptives did cut the coal directly, it still seems difficult to conceive that the heat traveling through the coal bed itself for two or three miles would have a profound effect, while that coming from an intrusive sill several hundred feet thick, and only a few feet distant would have no effect.

It is well known that coal is an exceedingly poor conductor of heat, much poorer than sandstones and shales, which lie between the coal and the intrusive sheets. Some idea of the relative conductivity of several of the beds in question may be gained from the following table of thermal conductivities of certain rocks as determined by Professors Herschel and Lebour, and Mr. J. F. Dunn, the conductivities being expressed in C.G.S. units: *

Sandstone,	.00545–.00565
Slate, along cleavage,	.00550–.00650
Slate, across cleavage,	.00315–.00360
Tough clay (sun dried),	.00223

* C.G.S. System of Units, J. D. Everett, London, 1891; pp. 125–127.

Tough clay (moist),	.00310
Coal,	.00057–.00113

Professors Ayrton and Perry found the conductivity of

Porphyritic trachyte,	.0059

It readily appears that the coal having the highest grade of conductivity is only about one fifth as good a conductor as ordinary dry sandstone, or as an igneous rock similar to that in the Cerrillos district. This being the case, and assuming that this series of beds is cut by the great intrusive mass to the south, it is interesting to determine how much of the heat concerned in the transformation of the coal at a given point would reach that point through the coal itself, and how much would reach it through better conductors such as the intrusive sheet.*

According to a well-known thermal law, the amount of heat that will reach a given point is equal to the difference in temperature between that point and the source of the heat, multiplied by the cross-section of the body through which it passes, multiplied by the conductivity of that body, divided by the distance it has to travel. This may be expressed in the following formula:

$$h = \frac{(T - t)sc}{d},$$

in which $h =$ the amount of heat that reaches the given point, $T =$ the temperature of the source of heat, $t =$ the temperature of the given point, $s =$ the cross-section of the body through which the heat travels, $c =$ the conductivity of that body, and $d =$ the distance the heat travels in reaching the given point.

Applying this law to the case under discussion, we have the intrusive mass of the Ortiz Mountains as the source of heat, while any portion of the anthracite bed will be the given point. We are to consider whether more heat will reach this given point through the coal itself or through the overlying intrusive sheet and the intervening sandstone and shales. For the moment we will neglect the additional heat of the sill itself, and see what the result would be if it were only the same temperature as the coal. As shown by Professor Stevenson, and noted by myself, good

* I submitted this problem to Professor Wm. Hallock, of Columbia University, and for his criticism and suggestions concerning the points noted below my acknowledgments are due.

anthracite is found at least two or three miles away from the intrusive mass of the Ortiz. Let us then assume the smaller number, two miles, as the distance, along the coal bed from the source of heat. The distance along the intrusive sheet and then down to the coal, would be this two miles plus the twenty-five to fifty feet of intervening sandstone and shales. In a distance of over 10,500 feet, twenty-five or fifty feet is a negligible quantity and may be dropped out, especially since the conductivity of the sandstone does not differ greatly from that of the sill, and since in some places the sill is only ten feet from the anthracite. In so short a distance the difference in conductivity across and along bedding would also be so small, relatively, as to be negligible. As the given point and the source of heat are the same in both cases, the difference in temperature $(T - t)$ will be the same in both cases, and may be stated as n degrees. The sill varies from at least 100 to 150 feet in thickness in the region in question, while the coal averages about three feet, the highest record being given as seven feet. If we take the lowest estimate for the sill, and the very highest estimate for the coal, then over any given area the sill will have a cross-section over fourteen times as great as that of the coal; whence $s = 1$ in the case of the coal, and $s = 14$ in the case of the sill. Taking the highest figures given for the conductivity of coal, we have $c = .00113$ in the case of the coal, and $c = .0059$ in the case of the sill. Substituting these values in the above formula, we have

$$h = \frac{n \times 1 \times .00113}{2} = .000565n$$

as the amount of heat reaching the given point through the coal itself, and

$$h = \frac{n \times 14 \times .0059}{2} = .0413n$$

as the amount of heat reaching the given point through the intrusive sheet. In other words over 73 times as much heat would reach the given point in the coal seam by coming through the intrusive sheet as would reach the same point through the coal itself.

This estimate is based on the worst possible conditions for the transmission of heat through the sill, and the best possible condi-

tions of transmission through the coal. A similar calculation, assuming average thicknesses of beds, conductivities, etc., gives a result of over 300 times as much heat coming to a given point through the sill as through the coal itself. The latter estimate is probably much nearer the truth than the former.

The above must be considered as only a rude approximation, so far as actual figures are concerned. But while the real conditions are far less simple than assumed above, owing to conductivity of heat by way of intervening sandstones, etc., the essential truth is clearly shown. Even had the sills no heat of their own, they would convey to the coal, as intermediate agents, vastly more heat that it would be possible for the coal itself to transmit. It may be doubted if the sills would conduct enough heat for two or three miles to effect the transformation to anthracite. Then, in the terms of our most conservative figures, it is seventy-three times as doubtful that the coal itself could transmit sufficient heat to accomplish the change.

The presence of water (conductivity = .00136) in the coal might increase its conductivity to some extent, but even if we were to suppose an improbable amount of moisture the increase would not be enough materially to affect the above figures. And at the same time the presence of water in the neighboring beds would correspondingly increase their conductivity.

So far we have ignored the actual heat of the sills themselves. If, now, we consider the initial heat of the intrusive sheets, sometimes over 300 feet in thickness in the Madrid area, we have a most reasonable explanation of the source of the transforming energy. The heat would readily spread through the thin beds of sandstone and clay shale, which are fairly good conductors, to the coal only a few feet distant. The rise in temperature, the resulting increased chemical activity and the possible influence of hot water and vapors, are all factors to be considered in connection with the change.

There are a number of facts which confirm the theoretical conclusions deduced. As shown in the Madrid section (Fig. 5), the upper large seam of coal is only a few feet from the sill above it. This coal is good anthracite. The lower seam is several times as far away from the sill nearest it, the one immediately below. This coal is bituminous. Midway between the two sills and so quite a distance from the intrusive, is a bed of shale with considerable un-

changed brown lignite. It is difficult to account for this condition upon any other hypothesis than the one now supported, that the sills were the active transforming agents. Believing this to be the case, we can readily understand how the heated lava, intruded as sills between a series of lignite beds, would produce the greatest change on the nearest beds making anthracite, affect those beds farther removed less profoundly giving bituminous coal, while the beds still more remote would remain as unchanged lignite.

It is interesting to compare the analyses of the coal and lignite from the above three seams. In the table given below the analyses, for which I am indebted to Mr. C. H. Decker of the Columbia School of Mines, have been recalculated on an ash-free basis, in order to afford a better means of comparison with the lignite in the lignitic shales. For while the brown lignite is well shown, and preserves the woody structure with great fidelity, it only constitutes about 22 per cent. of the samples secured. This does not affect the significance of the occurrence, since the presence of the foreign material would increase the conductivity of the beds, and facilitate the alteration of the lignite contained in them. In fact, similar beds near the upper intrusive sheet have been so altered, producing a peculiar, soft, black sandy rock. The anthracite and bituminous coal contained 7.70 per cent. and 5.04 per cent. of ash respectively. No. 1 is the recalculated analysis of the lignite in the lignitic shales from an exposure near the Madrid breaker, 134 feet or more from nearest intrusive sheet; No. 2 that of the bituminous coal, an average sample taken from carload just removed from bituminous mine near same point, 100 feet from nearest intrusive sheet; and No. 3 that of the anthracite, an average sample taken from carload from anthracite mine just above, less than 30 feet from intrusive sheet.

	No. 1.	No. 2.	No. 3.
Water	18.33	1.26	.86
Volatile hydrocarbons	61.91	36.49	6.55
Fixed carbon	19.76	62.25	92.59

The decreasing percentages of water and volatile hydrocarbons, and the increasing percentages of fixed carbon, from the beds farthest away from the intrusive to that nearest it, is even more striking than the variations in a north-and-south direction along the same bed, pointed out by Professor Stevenson. And while the

latter variations are what we would expect on the basis of either theory, the facts just noted above offer serious obstacles to the theory of a change effected by heat traveling along the coal seams from the south, and strongly confirm the theory that the heat from the intrusive sheets alone was the transforming agent.

Professor Stevenson noted the fact that thin beds of coal between the two main beds above referred to remained good bituminous coal far southward into the region where the beds above and below were both anthracite (C. C. F., p. 120). He recognized that this fact appeared to contradict his hypothesis, but explained the phenomenon on the ground that these smaller beds were badly cut by clay seams, which would prevent the passage of heat from one portion to another. Clay which has been sun-dried, the poorest conductor among clays, is twice as good a conductor of heat as coal; while the same material in a moist condition is three times as good a conductor. The clay seams should facilitate the passage of the heat, especially since the great pressure of overlying beds would make perfect contacts between clay and coal, and it seems to me that this striking contradiction to Professor Stevenson's hypothesis remains unexplained. If we regard the sills as the active agents, however, it is readily intelligible.

It is also to be noted that in every part of the field the anthracite coal is invariably close to one of the sills. It is also true that the bituminous coal is generally farther removed, or occurs near where a sill is thinning out to disappear entirely. In this latter association we find the bituminous coal of the northern part of the Lucas (White Ash) anthracite bed. Professor Stevenson has noted that in a drill hole on the mesa west of Coal Gulch, bituminous coal was found only 8 or 10 feet above a sill 200 feet thick. It does not seem to me that this can in any way cast doubt upon the theory supported. For while we might say certainly that where metamorphic action has been effective it was due to a certain cause, we can never say that such action shall extend a given distance from its source. Evidences of the unequal distribution of metamorphic action about an igneous mass are too numerous to need comment. And while in a general way we should look for a certain degree of uniformity, isolated cases of less extensive activity should not occasion undue surprise. Moreover, the case in question is from near the northern limit of the sill, and the abrupt termination of the latter near that place, or a possible local thickening

of the sheet bringing it so near the coal for only a very limited area, or the possible occurrence of a bed of loose sands (the thermal conductivity of which may sink as low as that of coal) between the coal and the sill, may explain the lack of excessive metamorphism on a most natural basis. The fact that the bed was changed to bituminous coal, instead of remaining lignite, is proof that the metamorphism was active to a considerable degree.

The fact that unaltered brown lignite, showing the detailed structure of the wood with remarkable clearness, occurs in the Cerrillos region where protected from the heat of intrusive sills by a considerable thickness of sands and shales and more especially by beds of poorly conducting coal, suggests that prior to the intrusion all the beds may have been of lignite. This conclusion gains weight from the fact that the lignites of the same horizon farther west are practically unchanged. After the transformation of the lignite into coal, as a result of the cooling and contraction of the beds, strains were developed, fractures and faults resulted, and extensive dykes were intruded. This accounts for the crushing, slickensiding and laminating of the coal, which is so prominent a feature in parts of the mines.

In his excellent paper on the "Coal Fields of Colorado,"* R. C. Hills has noted the fact that every stage of alteration from true lignite to true anthracite is found in the Colorado fields in connection with the associated intrusives. One excellent example is reported from the Clear Creek basin, where an intrusive sheet of lava, twenty feet thick, is separated from a ten-foot coal seam by fifteen to twenty feet of shale. In one place the lava jumps down to within eight feet of the coal seam, and continues thus for about 300 feet. This near approach of the intrusive transformed the coal into anthracite. Hills regarded the intrusive sheets as active agents, and emphasized the importance of increased chemical activity due to elevation in temperature, aided by the action of steam and hot water. Direct contact with the intrusive was shown not to be essential, and the existence of the coal in the form of lignite prior to the transformation pointed out.

As has already been shown both theoretical considerations and the actual facts in the field show that the close proximity of one of the great intrusive sheets is sufficient to produce the transforma-

* "Coal Fields of Colorado," R. C. Hills, Min. Res. U. S., 1892, pp. 319-365.

tion from lignite into coal. Indeed, it would seem incredible that an imprisoned sheet of molton rock, of wide extent, and from 300 to 400 feet thick in places, should not have a profound effect upon carbonaceous beds only a few feet distant. In the same way, on *a priori* grounds, we might expect that actual contact with the intrusive would have a detrimental effect on the coal, since intense and sudden activity of this nature would tend more to char and

FIG. 14. Columnar structure in coal.

destroy the coal than the slower and more steady action through protecting sediments. Observations in the Cerrillos field show that where a sheet or dyke cuts across the bed, whether it be bituminous or anthracite, the coal near the contact is destroyed, and in no case is anthracite produced from bituminous coal.

In the White Ash (bituminous) mine, now abandoned, a north-and-south dyke was encountered 3,600 feet from the mouth of the slope. For about 100 yards before the dyke was struck the bituminous coal was badly altered, being wholly worthless. So far as could be learned no anthracite was produced. This same obstruction was encountered in the Lucas (anthracite) mine 3,000 feet from the mouth of the slope, and the coal was similarly altered in the vicinity of the dyke there.

Professor Stevenson has already noted the influence of the Madrid dyke in effecting the change in the coal in a pit near the northern end of Madrid (C.C.F., p. 116).

In the Anthracite B No. 33 mine, east of Madrid, a sheet from below cuts up through the coal to a point just above it, and then follows along the bedding plane. The coal is excellent anthracite until within a hundred feet or so of where the sheet has cut it, when the change to soft, charred coal is noted. This "burned" coal from the anthracite bed is similar to the material produced in bituminous beds elsewhere by the same kind of action. In this same mine, in one of the right entries, the same sheet is encountered where it cuts up through the coal. At this point the coal is destroyed as before, while near the sheet beautiful curved, basaltiform columns of natural coke are formed (Fig. 14). The analysis of this coke, made by Mr. C. H. Decker, is given below:

Water,	4.55
Volatile hydrocarbons,	4.43
Fixed carbon,	84.67
Ash,	6.35
	100.00

In a coal mine east of the Ortiz Mountains a seam of bituminous coal is cut by one of the great radial dykes from that group. At the contact the coal is destroyed, while a short distance away, on either side, the bituminous coal is unchanged. Nothing in the nature of anthracite was produced.

The evidence points strongly to the conclusion that not only was direct contact not essential to the transformation of the lignite into coal, or of bituminous coal into anthracite, but that such direct contact tended to destroy both anthracite and bituminous coal alike, without producing anthracite from either lignite or bituminous coal.

Summary.

The probable relations of the coal beds to the Ortiz laccolith, the laws governing thermal conductivity, the relations of the anthracite and bituminous beds to the intrusive sheets or sills, the extent and form of these sills, the occurrence of unchanged lignite where protected from the heat from these sills, the effects produced by direct contact of intrusives on both bituminous and anthracite coal at several localities and the evident sequence of geological disturb-

MOUNT CHALCHIHUITL. (Showing portion of main excavation, with tree-covered dumps in middle ground.)

ances in the area, together with other minor considerations, would seem to justify the following conclusions, which were outlined at the beginning of this discussion:

The anthracite and bituminous coal of the Cerrillos region were produced by the metamorphic action of intruded sheets of lava upon beds of lignite.

Direct contact was not essential to the change; on the contrary, direct contact destroyed both anthracite and bituminous coal without the production of anthracite.

More gradual thermal action through intervening protecting beds of sand and shale was conducive to the production of the best grade of coal.

The coal was crushed and sheared by movements subsequent to the intrusion of the sills and the transformation to bituminous coal and anthracite.

TURQUOISE.

The turquoise deposits of the Cerrillos Hills early attracted the notice of geologists and explorers in this region. In 1858, Professor W. P. Blake published a paper entitled "The Chalchihuitl of the Ancient Mexicans, Its Locality and Association, and Its Identity with Turquoise."* The paper discussed the extent and antiquity of the old workings in the Cerrillos Hills, the geological associations of the turquoise, and the characters of the gem.

In 1874, Dr. Oscar Loew visited the hills, and in his report† gives a brief description of the turquoise deposits, together with an analysis of the gem. This analysis, together with several others of the Cerrillos material, is given in Part III. of his report.

In 1880 Professor Benjamin Silliman studied the Cerrillos turquoise deposits, and published notes on the "Turquoise of New Mexico."‡ Professor Silliman describes the ancient workings, discusses the character and origin of the turquoise, and the composition of the matrix. Illustrations of a longitudinal section and a distant view of the workings are given.

In the late '90's Dr. C. L. Herrick made several short trips to the Cerrillos district, and in a paper on "Geological Associations in New Mexico Mining Camps"§ discussed the origin of the turquoise.

* *Am. Jour. Sci.*, Vol. XXV, pp. 227–232, March, 1858.

† Report of Chief of U. S. Engineers, 1875, Part II, p. 1027.

‡ *Am. Jour. Sci.*, Vol. XXII, 67–71, July, 1881.

§ Rep. of Gov. of N. M. for 1900, pp. 257–260.

Professor J. S. Newberry (1859), Dr. J. L. LeConte (1867) and others made brief references to the turquoise deposits of this region, but gave no detailed descriptions.

In 1887 F. W. Clarke and J. S. Diller gave a detailed microscopical and chemical discussion of "Turquoise from New Mexico,"* based on collections made by Maj. J. W. Powell. The composition of the matrix was also considered and the origin of the gem discussed. A full review of their paper is given in connection with the discussion of the microscopical and chemical composition of the gem and its matrix, in Part III. of this report.

In 1900 Professor S. L. Penfield published an article on "The Chemical Composition of Turquoise."† An analysis of turquoise from Nevada is given, specimens of the Cerrillos material being examined and the analyses by Clarke, together with others, discussed. The copper is considered by Penfield as an essential constituent of the turquoise, rather than an impurity as suggested by Clarke.

The turquoise deposits of the Cerrillos Hills are found in two main localities, three miles apart. The extensive workings of the ancient Indians and Mexicans are located in Mt. Chalchihuitl (Plates M and N), a low knob east of Grand Central Mt. This is the locality described by Blake, Silliman, and others, and is of great historical interest. The hill is not represented by the contours on the map. Professor Silliman apparently confused Mt. Chalchihuitl, and the Grand Central Mt. just west. His descriptions of general appearance, altitude, etc., apply to the "dome" of Grand Central Mt., and do not apply to the low and inconspicuous knob of Mt. Chalchihuitl; whereas his descriptions of the rock, the excavations, and the cross-section and general view are of Mt. Chalchihuitl itself. In more recent years the mines have been worked to a small extent, but are now abandoned. The present workings of the American Turquoise Company of New York are situated at the southeastern end of Turquoise Hill (Plate O), a low ridge rising above the level of the plains northeast of the main group of hills. This locality is barely mentioned in the earlier descriptions, but was worked by the Indians probably as early as the more extensive excavations in Mt. Chalchihuitl, and in recent years has

* Bull. U. S. G. S., No. 42, pp. 39–44.

† *Amer. Jour. Sci.*, Vol. X., November, 1900, pp. 346–350.

MAIN EXCAVATION IN MT. CHALCHIHUITL. (Showing extent of ancient workings.)

proven of more economic value. Other minor deposits have been opened up, but no extensive developments made. Some of these, also worked to some extent by the Indians and Mexicans, are found at the western end of Turquoise Hill.

In all of these older workings the stone hammers of the ancient miners may be found to-day, although relic hunters have carried off the greater part of them, and only the more inferior specimens remain. The extent of the workings in Mt. Chalchihuitl is truly marvelous. The illustrations do not convey an adequate idea of the enormous mass of rock removed by the primitive methods of the ancients, although the figure in Plate N will give some conception of the depth which they reached. The whole north side of the hill has been quarried out in the search for the much prized "chalchihuitl," while less extensive excavations are found in other parts of the so-called mountain. It seems almost incredible that such a mass of rock could have been removed by a primitive people, without the aid of modern mining appliances. As Blake says, "This great excavation is made in the solid rock, and tens of thousands of tons of rock have been broken out." According to Silliman, a local surveyor found that the waste excavated in the old workings covers an area of at least twenty acres. All of the middle-ground in Plate M, on which piñon and cedar trees are growing, is débris from the workings just back, where the bare rocks are seen in the cliff. This "dump" forms a ridge or rim about the excavation, which latter extends to a depth not suggested by the picture.

The great antiquity of the workings cannot be doubted. The stone-hammers and fragments of pottery of the ancient miners, the rocks covered with lichens and gray with age, and the trees growing on the dumps and down in the pits, all bear witness to a period of mining activity centuries ago. Blake speaks of pine trees down in the pit which were over a hundred years old, while Silliman says their age must be reckoned by centuries. In 1680 a large mass of overhanging rock near the top of the cliff slid down, crushing a number of the Indian miners. This accident has been considered the immediate cause of the uprising of the Puebloes and the expulsion of the Spaniards in that same year. I was able to get far enough back through the débris of the slip to make out a part of the old roof of the cave formed by the overhanging cliffs. It was still black from the smoke of ancient fires, and served to give a very good idea of the great extent of the disaster.

The rock forming Mt. Chalchihuitl and the western and eastern ends of Turquoise Hill, and in which the turquoise occurs, is fully discussed in Part III. of this report. As is shown there, this rock is an altered phase of the augite andesite forming the main portion of the Cerrillos Hills. The main large areas over which this altered rock prevails are shown on the geological map. Those areas at Mt. Chalchihuitl and at either end of Turquoise Hill are the only ones which so far as known, contain any notable amount of turquoise. The rock is yellow or white in color, sometimes mottled or streaked with iron stains. In cases it may resemble sandstone, but remnants of the feldspar phenocrysts are generally seen in the hand specimen.

The turquoise occurs as seams throughout the rock, filling crevices formed by crushing and shearing, and as little nodules in streaks or patches of kaolin. The color varies from green through greenish-blue to pure sky blue. Many of the specimens are marred by streaks of limonite, kaolin, etc., but some gems of rare beauty and purity have been secured, equal to the best Persian material. The microscopic and chemical characters of the turquoise are presented in some detail in Part III.

Concerning the origin of the turquoise several opinions have been advanced. Professor Silliman regarded the alteration of the rock as probably due "to the escape * * * of heated vapor of water and perhaps of other vapors or gases, by the action of which the original crystalline structure of the mass has been completely decomposed or metamorphosed, with the production of new chemical compounds. Among these the turquoise is the most conspicuous and important. * * * Chemically it is a hydrous aluminum phosphate. * * * Evidently the decomposition of the feldspar of the trachyte furnished the alumina, while the apatite, or phosphate of lime, which the microscope detects in thin sections of the Cerrillos rock, furnished the phosphoric acid. A little copper ore is diffused as a constitutent of the veins of this region, and hence the color which that metal imparts."

Clarke and Diller considered the turquoise as having replaced veins of apatite. After noting the fibrous structure of the gem, and that the fibers run directly across the vein at right angles to the walls, and are arranged perpendicularly along the sides of small fissures running into or across the vein, they continue: "The perpendicular arrangement of the turquoise fibers along fissures cross-

TURQUOISE HILL. (Large dump from turquoise mine shown at the right.)

ing the vein indicates that the mineral may have been derived from the alteration of another substance with which the vein was formerly filled. We would suppose, of course, that the original vein material was itself a phosphate; and the only one after which turquoise is known to be pseudomorphous is apatite, a species which not infrequently occurs in veins. The opinion that the turquoise has resulted from such an alteration is favored by the presence of other alteration products, to be noted in considering the composition of the country rock in which the turquoise is found. It is also suggested by Hermann's analysis of blue Oriental turquoise, in which the equivalent of 3.41 per cent. of calcium phosphate was actually determined."

In 1900 Dr. C. L. Herrick expressed his opinion of the origin of the turquoise in the following words: "The syenite * * * has been intimately blended with fragments or great masses of the sedimentary rocks through which it has broken its way. These rocks were mainly Jura-Triassic and Cretaceous. It would appear from a careful study of the region that the turquoise owes its origin to action of the molten syenite on the copper-bearing sandstone of the Jurassic it had caught up in its escape."*

Concerning the above theories, the following facts may be urged against the latter one, that of an origin in the metamorphic action of molten lava on copper-bearing Jurassic sandstones: It is not clear what reactions would take place between molten lava and a sandstone to produce the turquoise, a non-siliceous mineral. The theory is not supported by any field evidence. The matrix of the turquoise, while resembling sandstone in places, is an altered igneous rock, as all students of this region agree. So far as I was able to find, there is no sandstone in the vicinity of Mt. Chalchihuitl. The inclusions of red sandstones farther east, while resembling the red beds of the Jurassic, are now known to belong to the late Cretaceous or Laramie, and carry no copper so far as observed.

As will appear from the petrographical descriptions in Part III. of this report, tourmaline occurs in the decomposed country rock, and its presence suggests some such action of escaping vapors, gases or waters, as is premised by Silliman. There is every reason

* "Geological Associations in New Mexico Mining Camps," Rep. of Gov. of New Mexico, 1900, p. 258.

to believe that the crushed and sheared zones in the andesite formed passage-ways for the active agents which effected the decomposition. Whether or not the turquoise was formed at that time as one of the new chemical compounds, as is supposed by Silliman, or is a later alteration product from apatite in veins, according to Clarke and Diller, is another question.

If the turquoise represents a replacement of veins of apatite, we should expect to find some trace of the original mineral in some of the numerous sections examined. Apatite, even when occurring in veins, usually but not always shows a greater or less development of the crystalline habit. In the Cerrillos case, no trace of apatite in veins has ever been found, and in no case does the form of the turquoise suggest the outline of some antecedent crystalline mineral. On the other hand, apatite does occur in the country rock as tiny crystals, but so far as seen was never replaced by turquoise.

It does not seem to me necessary to assume the former existence of veins of apatite in the rock in order to explain the existence of the turquoise in its present condition. The appearance under the microscope suggests rather that the gem formed in the crevices directly, as one of the alteration products of the various minerals constituting the country rock. That the alumina of the turquoise was derived from the decomposing feldspar of the andesite, as suggested by others, seems most probable. And it seems equally probable that the apatite, occurring as an accessory mineral in the andesite, furnished the phosphoric acid. The fact that Clarke and Diller failed to find apatite in their sections is not surprising in view of the greatly decomposed character of the specimens examined by them. For while this mineral is usually abundant in all the fresher portions of the rock, sometimes occurring as quite large crystals, it is seldom seen in the more decomposed portions containing the turquoise; which is just what we should expect on the basis of the theory as to origin here supported.

The copper, which Clarke, Diller and others regarded an an impurity, but which according to Penfield is an essential constituent of the mineral turquoise, was probably supplied from the same copper-bearing solutions, possibly indirectly, which gave rise to the copper-bearing ores of the region. In the mines of the American Turquoise Company the copper is found forming a green coating

on the walls of the tunnels, etc., wherever the rock is left undisturbed for any length of time.

The intimate association of fluorite with the turquoise is very suggestive. As shown in Part III. of this report, the relations and appearance are what we should expect if the turquoise formed first, leaving the fluorine of the apatite to make fluorite, which latter formed about the turquoise. The proportion of the fluorite to the turquoise is suggestive of the proportion of fluorine to phosphoric acid in apatite, the fluorite being a minor factor as regards quantity.

Metallic Minerals.

While the Cerrillos Hills have never produced much in the way of metallic minerals, the region was once the scene of no little mining activity, and every summer still finds a number of active prospectors' camps in operation and perhaps one or two small mines. In the late 70's and early 80's Carbonateville and Bonanza City, now marked only by the ruins of old buildings or by a few Mexican adobes, were booming mining camps.

Prospecting parties spreading southward along the Rockies after the great Leadville excitement overran the mountains of northern and central New Mexico. One of these parties took up claims in the Cerrillos Hills, where were found ruins of mines of great antiquity, evidently worked and then abandoned by the Indians. The news of the numerous northeast and southwest "veins" in these hills soon attracted a goodly company of miners, and the most prosperous days of the Cerrillos region began. Claims were located everywhere on the very numerous mineralized belts, and the hills were fairly honeycombed with small shafts, tunnels and open cuts, most of them of very limited extent. A few enterprises on a larger scale were undertaken, and some ore shipped from the neighborhood of the Cash Entry and Grand Central mines.

The camp was not long-lived, however. Doubtless the early miners found the richness of the veins themselves less seductive than was the number of them. To the fall in the price of silver, the failure of two patent smelter schemes and also of one of the larger mining enterprises is popularly attributed the failure of the camp.

The ores of the Cerrillos region are in the main lead-silver and zinc, carrying a little gold, and more or less copper. At the sur-

face the ores are chiefly in the oxidized form, but pass into the sulphides in depth. In most instances the ore occurs in sheared zones having a northeast-southwest trend. The movements producing this extensive shearing have already been referred to. It would seem that the ore-bearing solutions arose along these crushed zones, giving rise to the numerous mineralized belts which attracted the early miners. True fissure veins are also encountered, but are less common. Both shear zones and veins approximate the vertical.

The direction of the strike, as well as the number of these mineralized belts, is well shown by the accompanying reproduction (Plate P) of a portion of one of the old mine maps, which represents the various openings, together with the strike of the ore bodies.

THE PRODUCTION OF ANISIC ACID BY THE OXIDATION OF ANISEED OIL.*

BY MARSTON TAYLOR BOGERT AND CARL H. ZIEME.

(Contribution from the Havemeyer Laboratories of Columbia University, No. 89.

In 1840 Laurent† announced that by the action of nitric acid upon the volatile oil of tarragon he had discovered five new crystalline acids. The following year‡ he mentioned three of these more specifically, calling them "draconic," "nitrodraconasic" and "nitrodraconesic" acids, the two latter being respectively mono- and dinitro derivatives of draconic acid; while, in a third article§ he described them more fully, outlining also their method of separation.

Cahours, at about the same time (1840), investigated the action of nitric acid upon anethol. He first reported‖ that the action of dilute nitric acid gave a new acid, while with strong nitric acid a nitro acid was formed to which he gave the name "nitranisic" acid. In a later and more extended paper¶ the details of the

* Read before the New York Section of the American Chemical Society at its meeting June 5, 1903.

† *Comptes Rendus*, *10*, 531 (1840).

‡ *Comptes Rendus*, *12*, 765 (1841).

§ *J. prakt. Chem.* (Erdmann), *27*, 232-243 (1842).

‖ *Ann.* (Liebig), *35*, 312 (1840).

¶ *Ann. chim. phys.*, III., *2*, 287, 288, 301 (1841), and *Ann.* (Liebig), *41*, 65, 66, 73 (1842).

PORTION OF OLD MINE MAP OF CERRILLOS HILLS. (The little bars through the dots show the direction of lode in each excavation.)

work are given, and the new acid is christened "anisic" acid. The formation of a yellow resin was also noted in those reactions where strong nitric acid was used and the name "nitranisid" suggested for it.* At the beginning of the reaction there is always formed a heavy red oil which contains, in addition to anisic acid, varying amounts of anisic aldehyde.†

Gerhard,‡ after a careful comparison of these products, came to, the conclusion that Laurent's "draconic" and "nitrodraconasic" acids were identical with Cahour's "anisic" and "nitranisic" acids.

Persoz § oxidized oils of anise, star anise and fennel with potassium dichromate mixture, and separated from the product, acetic "umbellic" and "badianic" acids. At Liebig's suggestion Hempel || repeated this work and found Persoz's "umbellic" acid to be identical with Laurent's "draconic" and Cahour's "anisic" acid, and also came to the conclusion that there was no difference between the so-called "badianic" and "umbellic" acids. Zervas ¶ also prepared anisic acid from oil aniseed by oxidation with dichromate mixture, the yield being 50 per cent. of the weight of the oil used. By altering the strength of the dichromate mixture, and changing somewhat the operating conditions, Ladenburg and Fitz** brought the yield of anisic acid up to 55–75 per cent. The composition of the oxidizing mixtures used by Persoz, Zervas and Ladenburg and Fitz varied as follows:

		Persoz.	Zervas.	Ladenburg and Fitz.
Oil	=	6	6	6
$K_2Cr_2O_7$	=	50	36	30
H_2SO_4	=	110	42	60
H_2O	=	400	54	120

The yield reported by Ladenburg and Fitz has recently been corroborated by Jackson.†† Where dichromate is the oxidizing

* This was subsequently shown to be a dinitroanisoin.

† Cahours, *Ann. Chim. phys.*, III., *14*, 483 (1845). Compare also Limpricht, *Ann.* (Liebig), *97*, 364 (1856); Städeler and Wächter, *ibid.*, *116*, 161 (1860); Landolph, *Comptes Rendus*, *81*, 97 (1875).

‡ *Ann. chim. phys.*, III., *7*, 293 (1843).

§ *Comptes Rendus*, *13*, 433–435 (1841).

|| *Ann.* (Liebig), *59*, 104–107 (1846).

¶ *Ann.* (Liebig), *103*, 339 (1857).

** *Ann.* (Liebig), *141*, 248 (1867).

†† *Am. Chem. J.*, *29*, 104 (1903).

agent employed, considerable anisic aldehyde is invariably formed, the amount increasing if the violence of the reaction is modified.*

Garelli,† by oxidizing anethol with alkaline potassium permanganate, obtained anisic and p-methoxyphenylglyoxalic acids. Bougault,‡ in his study of the successive steps in the oxidation of anethol, used alkaline permanganate to pass from p-methoxyacetophenone to p-methoxyphenylglyoxalic acid, and acid permanganate to convert the latter to anisic acid.

So far as the authors are aware, the efficiency of potassium permanganate as an oxidizing agent for the preparation of anisic acid from oil aniseed has not been investigated. It seemed, therefore, worth while to make a few experiments in this direction, comparing the results with those obtained by the other methods, and the work is given below in detail.

Nitric acid is not satisfactory as an oxidizing agent, on account of the formation of nitrated bodies, resins, etc., and the difficulty of purifying the product. It is therefore rarely used for the production of anisic acid. As between the dichromate and acid permanganate methods, there appears to be but little choice. Both are rapid and easily carried out, and in our experiments, the yields of anisic acid were approximately the same. It should be recalled, however, that other workers have obtained much better yields with the dichromate mixture than we report. The most rapid method for obtaining a crude anisic acid in fair yield is by the use of dichromate, but the product is not nearly so pure as the crude acid obtained by the acid permanganate oxidation. To secure anisic acid of the same degree of purity, we found, took just as long with the dichromate method as with acid permanganate, on account of the difference in the purity of the first products.

The oil used in the following experiments was a high grade oil of star aniseed furnished by Dodge & Olcott, of New York City.

Experimental.

I. Oxidation with Nitric Acid.—The strength of the acid used by Cahours, and which he found to give the best yields of anisic acid from anethol was 22°–23° Bé ; *i. e.*, approximately a sp. gr. of 1.18–1.19. In the following experiments an acid of sp. gr. 1.19 was employed.

* *Städeler, J. prakt. Chem.* (Erdmann), *103*, 105 (1868); Rossel, ibid., *151*, 28 (1869).

† *Gaz. chim. ital.*, *20*, 693 (1890).

‡ *Comptes Rendus*, *132*, 784 (1901).

1. Twenty-five gms. of the oil and 380 gms. nitric acid (sp. gr. 1.19) were mixed and left at ordinary temperature. No reaction occurred at first, but after standing for many hours a heavy red oil settled out. The mixture was allowed to stand several days longer, and the anisic acid was then precipitated by diluting with a liter of cold H_2O. The yield, however, was insignificant.

2. The same amounts of oil and acid were used as in the above. The acid was placed in a large beaker, heated to 90°, and the oil added slowly with constant stirring, the operation lasting about three hours. The anisic acid formed was then precipitated by adding a liter of cold H_2O, filtered out and washed thoroughly. This crude acid contains resinous by-products, from which it is freed by digesting with dilute ammonia, filtering, carefully neutralizing excess of ammonia with hydrochloric acid, boiling with boneblack, precipitating the filtered solution with excess of hydrochloric acid and allowing the same to cool down slowly. This gives a well crystalized product, although slightly yellow in color and of low melting-point (170°, uncorr.). The yield was 28 per cent. the weight of the oil used.

3. Same amounts of oil and acid as before, but the two were mixed all at once and the mixture heated immediately on the water-bath. During the first period of the reaction but little change was apparent. The oil gradually turned dark and increased in density until, after about an hour's heating, it slowly sank to the bottom. At this point the reaction tended to become rather violent, evolving CO_2 and nitrous vapors. It was, therefore, moderated somewhat by gentle external cooling, not allowing the temperature, however, to fall below 85°. The heavy oil gradually became more opaque, slowly rose to the surface, and the evolution of gas nearly ceased. To make sure that the reaction was complete, the heating was continued for nearly half an hour longer. The solution was then diluted and the anisic yield recovered as already outlined. Yield, 24.6 per cent.; melting-point low (170°).

4. The last experiment was repeated. Yield, 26 per cent.; melting-point low (172°).

As will be seen from the above, the anisic acid obtained by the use of nitric acid as an oxidizing agent was invariably impure, slightly yellow in color and of low melting-point. Cahours changed the acid to the ammonium salt, purified this by recrystallization, converted this to the difficultly soluble lead salt, decom-

posed the lead salt with hydrogen sulphide, and sublimed the acid thus obtained. Such a process is, of course, slow and unsatisfactory. We therefore studied the effect of stannous chloride as a decolorizing agent in this connection. Twenty-five grams of the yellow acid were dissolved in dilute ammonia, the solution diluted to 750 c.c., heated to boiling and acidified with 10 c.c. of hydrochloric acid; 10 grammes of acid-washed boneblack was added, and then 4 grams of stannous chloride in small portions and with constant shaking. The solution was then made slightly alkaline with sodium carbonate, metastannic acid filtered out, and anisic acid precipitated in the filtrate by acidifying with hydrochloric acid. Considerable coloring matter was removed in this way, but the same result was accomplished more readily by boiling a neutral aqueous solution of sodium anisate with boneblack, precipitating anisic acid in the filtrate, and washing the precipitate with a large amount of cold water, which dissolves out the yellow coloring matter without causing any appreciable loss of anisic acid.

II. *Oxidation with Potassium Dichromate Mixture.* — In this process the reaction becomes quite violent. Attempts to moderate it, however, only diminish the yield of anisic acid.

1. The first experiment was undertaken according to the directions of Ladenburg and Fitz. One part of oil aniseed (100 gms.) was poured into a solution of five parts potassium dichromate, ten parts sulphuric acid and twenty parts water, the temperature of the oxidizing mixture being 50°. The reaction soon became so violent that most of the material boiled out of the flask.

2. In this case only 25 gms. of oil were used with a proportionate amount of the oxidizing mixture. As before, the oil was added all at once to the dichromate mixture, the temperature of the latter being 50°. After the addition of the oil a violent reaction quickly set in, the temperature rising to about 125°. In ten minutes this reaction was over. The mixture was then diluted with about a liter of water and allowed to cool, the anisic acid being recovered from the product as described below. Yield, 48.2 per cent.

3. One hundred grams of oil were used, 50 gms. being added at first, with the intention of adding the remaining 50 gms. after the first reaction had ceased. An attempt was also made to control the temperature by external cooling. The reaction, however, set in so vigorously that it could not be satisfactorily controlled.

4. One hundred grams of oil were allowed to flow slowly into the dichromate mixture, stirring constantly with a turbine. The temperature of the dichromate solution was 60° at the beginning of the operation, and was gradually raised so that it registered 80° when 75 gms. of the oil had been added, at which point it was kept during the addition of the rest of the oil. The duration of the operation was about three hours. Yield of anisic acid, 41.8 per cent., melting at 183°–184° (uncorr.).

5. The above experiment was repeated, using instead of potassium dichromate an equivalent amount of the more soluble sodium salt. The crude anisic acid obtained, however, proved more difficult to purify, owing to oily by-products, six extractions with dilute ammonia being necessary to recover all the acid. Yield, 41.6 per cent.; melting point 182.5°–183° (uncorr.).

6. The potassium dichromate mixture was placed in a large battery jar and warmed on the water-bath. When the temperature of the oxidizing mixture reached 50°–55°, 100 gms. of the oil was slowly run in with constant stirring. As considerable heat is developed in the reaction, the hot water of the bath was gradually displaced by cold, and the addition of oil so adjusted that the temperature remained at 50°–60°. After half the oil had been oxidized the reaction proceeded much more smoothly. A little over two hours was consumed in adding the oil. The mixture was then allowed to cool slowly and stand over night. The mass was filtered and the precipitate washed with water until the washings were colorless. The crude anisic acid thus obtained was digested on the water-bath for several hours with dilute ammonia, the solution filtered and anisic acid precipitated by acidifying the filtrate. The removal of ammonium salts is facilitated by heating the solution to boiling, whereby the anisic acid is redissolved, and then by slow cooling it will separate in good crystals which can be easily filtered and washed. For further purification, the acid is added to about fifteen times its weight of water, the temperature raised to boiling, solution exactly neutralized with alkali, boiled with boneblack, filtered, anisic acid precipitated in the filtrate by acidifying strongly with hydrochloric acid, recrystallized from boiling water, and crystals washed free from all mineral acid. Yield, 32.4 per cent.; melting-point 183° (uncorr.).

7. The following experiment was made to ascertain the action of the oxidizing agent upon anisic acid itself. Fifty grams sulphuric

acid, 25 grams potassium dichromate and 100 c.c. of water were mixed, and 5 grams of pure anisic acid added to the mixture. At first no change was observed, but after heating on the water-bath the mixture gradually turned darker. After heating for two hours, the anisic acid was recovered and found to have lost 18 per cent. in weight. Too long heating of the oil with the dichromate mixture is, therefore, likely to diminish the yield of anisic acid.

It will appear from the above that a short, sharp oxidation is likely to give the best yield of anisic acid, those experiments in which the temperature was controlled and the duration of the operation prolonged showing lower results.

III. *Oxidation with Potassium Permanganate.* — A. *In neutral solution.*

1. Fifty grams of oil were added to a solution of 165 grams potassium permanganate in 2,200 c.c. of water, the whole being kept at 20° for three weeks. At the end of this time considerable manganese dioxide had separated, and the oil, judging by the odor, had all been oxidized. Excess of permanganate was destroyed by the addition of alcohol, the precipitate filtered out, and anisic acid precipitated in the filtrate by the addition of hydrochloric acid. Yield, not over 5 per cent., the product showing a low melting-point and possessing a pleasant aromatic odor.

2. A solution of potassium permanganate was prepared of such a strength that 11 c.c. contained 4 grams of available oxygen, and 25 grams of oil was oxidized by this solution at 90°, the amount of permanganate used being sufficient to oxidized 25 grams of anethol. In less than half an hour the oxidation was complete; but it was evidently too extensive, for only a very small amount of anisic acid was recovered.

3. A solution only half the strength of the above was used, the oxidation being conducted at 95°–100° for 12 hours, with constant stirring. After about three hours heating manganese dioxide began to separate and the solution showed an alkaline reaction. At the end of twelve hours most of the permanganate was decomposed. Upon working up the product, a yield of between 5 per cent. and 10 per cent. of anisic acid was obtained.

The mother-liquors from the separation of the anisic acid in the foregoing experiments were evaporated to dryness, the residue extracted with absolute alcohol, the alcohol driven off and the

residue repeatedly crystallized from benzene. The product was a crystalline solid, melting sharply at 88.7° (corr.), which melting-point could not be altered by further recrystallization. It was identified as p-methoxyphenylglyoxalic acid, for which Garelli * gives the melting-point as 89°.

B. *In Alkaline Solution.*—1. 25 grams of oil and 100 c.c. of strong (1 : 8) permanganate solution were placed in a two-liter flask provided with a return condenser, and the mixture heated to boiling; 12.5 grams potassium hydroxide were then added, and a weaker permanganate solution (1 : 10) run in from time to time until the pink color was no longer discharged on boiling. This took about two hours and three quarters, the amount of permanganate solution added being 1,250 c.c. Yield of anisic acid, 24 per cent.; melting-point, 183° (uncorr.).

2. The above experiment was repeated with 100 grams of oil. Eight hours were consumed in adding the permanganate solution, the amount necessary to give a permanent pink color being equal to 300 grams of solid permanganate. The filtered solution still showed a strong alkaline reaction and a faint aromatic odor. The yield was practically identical with the first experiment.

Several other lots of oil were oxidized, using permanganate and alkali in varying proportions, but the yields of anisic acid never exceeded 25 per cent.

C. *In Acid Solution.* — 1. Twenty-five grams of oil were mixed with about 100 c.c. of permangate solution (1 : 8), 125 grams sulphuric acid added, and the mixture boiled in a flask with a return condenser, adding more permanganate solution from time to time until 125 grams of the dry salt had been used. The duration of the oxidation was three quarters of an hour. Owing to more extensive oxidation this amount of permanganate was decomposed before more than half of the oil was oxidized, so the products were not further examined. The calculation of the amounts of acid and permanganate necessary were based upon the following equation :

$$5C_6H_4OCH_3C_3H_5 + 8KMnO_4 + 12H_2SO_4 = 5C_6H_4OCH_3COOH + 5CH_3.COOH + 4K_2SO_4 + 8MnSO_4 + 12H_2O.$$

2. The above experiment was repeated, using only 100 grams of sulphuric acid, but with no better results; 200 grams of acid could be used and yet all the oil did not disappear.

* *Gaz. Chim. ital.*, 20, 694 (1890).

3. Twenty-five grams of oil were oxidized by the action of a solution of 100 grams permanganate and 30 grams sulphuric acid, at 85°–90°, the permanganate being used in dilute (1 : 9) solution. The yield of anisic acid was 52 per cent. and the product was much purer than that obtained from the nitric acid or dichromate methods. The basis of the proportions used was the following equation:

$$3C_6H_4OCH_3C_3H_5 + 8KMnO_4 + 4H_2SO_4 = 3C_6H_4OCH_3COOH + 3CH_3.COOH + 4K_2SO_4 + 4MnO_2 + 4H_2O.$$

4. One hundred grams of oil were mixed with 500 c.c. of a 1 : 9 permanganate solution, and 100 grams of sulphuric acid diluted with an equal volume of water added. The mixture was stirred mechanically, the temperature being maintained at 90°, and warm permanganate solution of the same strength run in from time to time. By careful operation, the oxidation can be completed in an hour and a half. About 400 grams of permanganate were necessary to carry the oxidation to the point where the odor of anise had entirely disappeared, and the solution was then neutral to methyl orange. Anisic acid was extracted by treating the mixture with alkali, filtering and precipitating the filtrate with hydrochloric acid. As thus precipitated, the anisic acid is practically pure. Yield, 52.9 per cent.; melting-point, 183° (uncorr.).

5. To ascertain the yield when enough permanganate was used to permanently color the solution, 25 grams of oil were oxidized with 132 grams of permanganate, but the yield of anisic acid was no better than when only 100 grams of permanganate were used.

6. One hundred grams of oil were added gradually to 500 c.c. of a 1 : 9 permanganate solution at 50°, and then 60 grams of sulphuric acid poured in. The reaction was quite violent at first, the temperature of the mixture rising to 90°. As the reaction moderated more permanganate was run in, the addition of fresh permanganate causing less and less rise of temperature, and it was necessary finally to heat the mixture, to keep the temperature at 90°. After 3,600 c.c. of the permanganate solution had been added, the color of the mixture remained purple after heating for two hours longer, but the anise oil was not completely oxidized, on account of the deficiency of sulphuric acid. The yield of anisic acid was 26.7 grams; melting-point, 180°–181°.

The proportions of sulphuric acid and permanganate giving the best yields are, therefore, those given in experiments 3 and 4.

7. One hundred grams of pure anisic acid were added to a solution of 20 gms. permanganate in 180 c.c. of water and containing 6.1 gms. sulphuric acid. The mixture was heated to 90° and a vigorous oxidation immediately set in with evolution of considerable CO_2, the permanganate being destroyed in half an hour. On recovering the anisic acid, it was found to have lost 28 per cent. in weight. Too long an oxidation of anise oil with permanganate will, therefore, diminish the yield of anisic acid.

The anisic acid obtained in these experiments, when boneblacked and recrystallized from water and then from alcohol, melted sharply at 184.4° (corr.).

All the experiments were carried out quantitatively, the mother-liquors and washings being worked over in every case. The yields are given in percentage weight of oil used.

The best yields from the different methods were with nitric acid, 28 per cent.; with dichromate, 48.2 per cent.; with acid permanganate, 52.9 per cent.

ORGANIC LABORATORY, HAVEMEYER HALL,
COLUMBIA UNIVERSITY, June, 1903.

ABSTRACTS.

ANALYTICAL CHEMISTRY.

By ELWYN WALLER.

Deterioration of Platinum Crucibles. Heraeus (*Zts. angew. Chem.*, XV., 917). Deterioration has been frequently observed when precipitates of $MgNH_4PO_4$ are ignited in platinum. The author notes: (1) That the same effects are observed whether the metal is pure or alloyed with Ir. (2) The phenomena are due to the formation of P (3) which is reduced by the action of C on $Mg_2P_2O_7$ at 950°. (4) The reducing gases, especially H, produce the same phenomenon at 900°. (5) NH_3 is dissociated at a high temperature, and on account of the H it contains is eminently a reducing gas. (6) This precipitation is the more intense if the precipitate contains Newbauer's H_4O_4tc)geiN_2.

The obvious conclusions are that theMaroP a)ttln should be so managed as to prevent the formation of Newbauer's salt; that the heat should be applied gradually at first, to completely expel the NH_3 before the dissocation temperature is reached. It is not advisable to collect and ignite successively several precipitates in the same crucible, as is often done. In that case the ammonia of the later precipitate may react with the phosphate of the preceding ones.

Treating the precipitate at once with HNO_3 and igniting is the best way of avoiding such attack.

Ammonia. Substitute for Nessler's reagent. Manget and Marion (*Ann. de Chim. Anal.*, VIII., 83). Diaminolphenol, commercially called "amidol," is said to give a color reaction more delicate than the Nessler for free ammonia.

Potassium in Kainit. Rapid determination. Passon (*Zts. angew. Chem.*, XV., 1263). Place 10 gms. in a 500-cc. flask, add 300 cc., dilute HCl and boil, adding excess of $BaCl_2$ to obtain KCl. Cool, fill to the mark with 96 per cent. alcohol, cool, and bring to the mark. Filter through a dry filter. Take 25 cc. of the filtrate (=0.5 gm.), add 5 to 15 cc. $PtCl_4$ solution, and 125 cc. of 96 per cent. alcohol, agitate for five minutes and then filter through a Gooch. Wash with alcohol, rinse with ether, dry and weigh. Dissolve out K_2PtCl_4, wash with alcohol dry and weigh again, the loss is K_2PtCl_4, from which per cent.of K_2O may be calculated.

Manganese in Steel. Ramorino (*Monit Sci.* [4], XVI., 419). In using the Volhard method—solution in HNO_3, precipitation by ZnO and titration of the filtrate with standard $K_2Mn_2O_8$, the presence of the carbon compounds gives trouble unless some (usually) time-consuming method is used to destroy them. The author finds that they can rapidly be eliminated by the following treatment: Dissolve 2 gms. of the steel in 30 cc. HNO_3 (gr. 1.20). Boil out nitrous fumes, and then add 10

cc. conc. HCl with 10 cc. strong Br water. Boil until Br fumes are expelled. Dilute with about 200 cc. water, add 25 gms. ZnO in 200 cc. boiling water, allow to settle, and titrate with standard $K_2Mn_2O_8$. By a blank test the correction for impurity of the ZnO should be ascertained. This may be from 0.5 to 1 cc. when 1 cc. $K_2Mn_2O_8$ = 0.00119 Mn.

Volumetric for Zinc. Clewnell (*Ch. News*, LXXXVII., 121). The method depends on precipitation of the Zn in alkaline solution with standard Na_2S, and determining the excess of Na_2S by adding $KAgCy_2$, which reacts thus:

$$Na_2S + 2KAgCy_2 = Ag_2S + 2NaCy + 2KCy.$$

The excess of free cyanide (NaK)Cy is then titrated with standard $AgNO_3$ using KI as indicator.

The most convenient strengths for the solutions are:

(*a*) Na_2S solution about 0.2 per cent. (20 gms. per liter).

(*b*) $AgNO_3$ 5.215 gms. per liter gives a solution of which 1 cc. = 0.001 gm. Zn, but any solution of known strength may be used.

(*c*) $KAgCy_2$. To a KCy solution of 2 to 3 per cent. strength, add $AgNO_3$ solution until a slight permanent precipitate forms, then settle and filter.

(*d*) KI one per cent. solution.

Dissolve the ore, or other material, in any convenient manner, make strongly alkaline with NaOH, boil, dilute and filter if necessary. Run in a measured volume of solution *a* slightly in excess of what may be necessary to precipitate the Zn, agitate well, and then add a little CaO to assist settlement. Filter the whole, or an aliquot portion, and to that add a slight excess of solution *c*. Filter off the Ag_2S, and wash (prompt separation of the precipitate may be assisted by adding a little CaO at this stage). To the filtrate add about 5 cc. of solution *d* and titrate with *b* until a slight yellowish turbidity is permanent. 1 gm. KCy = 0.3 gm. Na_2S = 0.25 gm. Zn. Standardize by use of a solution containing a known amount of Zn.

Separation (*Qualitative*) *of Arsenic, Antimony and Tin.* Walker (*Proc. Chem. Soc.*, XVIII., 246). Add Na_2O_2 to the alkaline sulphide solution of the three and boil. Any Hg, if present, will separate at this point as HgS. Add excess of NH_4Cl and boil. H_2SnO_3 will be precipitated. Add excess of acid, and pass H_2S in the cold, Sb_2S_5 will precipitate, while H_3AsO_4 remains in solution.

Arsenic in Glycerin. Bougault (*J. Pharm. et Chim.* [6], XV., No. 11). Dissolve 20 gms. sodium hypophosphite NaH_2PO_2 in 20 cc. water and add 200 cc. HCl (gr. 1.17), filter off the precipitated NaCl through cotton wool. To 5 cc. of the glycerin add 10 cc. of this reagent. Immerse the test-tube in a boiling water bath, a brown coloration, or brownish flocculent precipitate is indication of As. 0.004 gm. As_2O_3 per liter can be thus detected.

Reagents in Estimating Arsenic. W. Thomson (*Ch. News*, LXXXVI., 179). The author criticizes the report of the Joint Committee of Soc. Chem. Ind., and Soc. Pub. Anal. Their method of

purifying HCl by Br or HBr he does not find satisfactory. His method is to dilute with about one third its volume of water, add about 1 gm. per liter of CrO_3 and distil, subsequently drawing air through the distillate.

H_2SO_4 is purified in essentially the same manner, adding CrO_3 (without diluting) and distilling.

HNO_3, he asserts, is seldom free from As. The same is said of Zn. The presence of small amounts of Fe holds back some As.

The details of manipulation of beer, etc., should be consulted in the original paper.

Assay for Gold and Silver in Cyanide Solutions. Chiddy (*Eng. and Min. Jour.*, LXXV., 473). Four assay tons (or more) of the solution are treated with 10 cc. of 10 per cent. $Pb(C_2H_3O_2)_2$ and 4 gms. zinc shavings, boiled a short time, and 20 cc. HCl added. When the Zn is all dissolved bring to a boil, wash the lead sponge with hot water, transfer to a filter paper, finally squeeze down to a lump — and place directly in a hot cupel. In case there is but little else than gold present, it may be advisable to add at the start some $AgNO_3$ dissolved in KCy.

Arents (*ib.*, 446) acidifies the cyanide solution with H_2SO_4, adds about 1 gm. of cement copper and boils, then filters and fuses with litharge borax and soda, and then cupels the button.

Gravimetric for Tellurium. MacIvor (*Ch. News*, LXXXVII., 17). Review of methods. Berzelius originally prescribed SO_2. Fresenius added to that the requirement that it should be performed in HCl solution. The formation of H_2SO_4 interferes with the completeness of the reaction, hence Whitehead proposed the use of $NaHSO_3$.

Frerichs uses KI besides the HCl and SO_2 with good results, especially as regards rapidity.

Crane proposes the use of metallic Mg. The oxidation of the Te during washing and drying appear just about to balance the small amounts of Te which escape precipitation. Description of a satisfactory method is promised.

Vanadium Titration. Gooch and Gilbert (*Am. Jour. Sci.*, XV., 389). To reduce V_2O_5 in order to titrate with standard $K_2Mn_2O_8$ the zinc reductor can be used as well as for Fe solutions. Jones' reductor as originally described was rather elaborate. The simplified form, described in Blair's "Chemical Analysis of Iron," is quite as efficient. Some V_2O_3 may be formed. To bring the whole of the V to the condition of V_2O_4 before titration, the solution from the reductor was run into about 100 cc. of saturated solution of Ag_2SO_4. The solution on boiling affords the Ag in spongy mass, which is readily filtered and washed, and the filtrate (again heated to boiling) is titrated with standard $H_2Mn_2O_8$.

Molybdenum. Qualitative. Spiegel and Miass (*Berichte.* XXXVI., 512). Dissolve one part colorless phenylhydrazine in four parts of 50 per cent. acetic acid. Add 5 cc. of this solution to the solution to be tested and boil one or two minutes. A red coloration indicates the presence of Mo.

If the amount is very minute, cool to 50° C. and shake with chloroform or acetic ether, which will dissolve the red compound, and make it more apparent. 0.01 mgm. in 10 cc. may thus be detected.

The only thing liable to be misleading is As_2O_5 when in very concentrated solutions, which affords a yellowish red with separation of C_6H_6.

Uranium Tests. Aloy (*Bull. Soc. Chim.* [3], XXXVII., No. 14). Adding H_2O_2 and then K_2CO_3, either solid or in concentrated solution, gives with UO salts a solution of red coloration. $KHCO_3$ cannot be used instead of the neutral carbonate. The reaction will occur in the presence of metals giving precipitates insoluble in K_2CO_3 solution. The addition of three or four volumes of alcohol to the red solution precipitates the red compound. The composition of this precipitate is being examined—a matter of some difficulty, as it is very unstable. The reaction may be used as a test for H_2O_2 mutatis mutandis.

Sulphur in Gunpowder. Petersen (*Chem. Zt.*, XXVI., 104). Boil with an alkali thus dissolving the S. Add H_2O_2—warm—acidify with HCl and precipitate with $BaCl_2$. The method is applicable also to many organic sulphur compounds.

Boric Acid. Cassal and Gerans (*Ch. News*, LXXXVII., 27). The turmeric test for H_3BO_3 is modified, possibly rendered something different and more delicate by addition of $H_2C_2O_4$. The color obtained is a magenta red, and the reaction can be used quantitatively (colorimetric). In milk, for example, 15 to 20 gms. of the sample are rendered decidedly alkaline by $Ba(OH)_2$, evaporated to dryness and finally carbonized. The residue is treated with water, the solution made just acid with HCl, and extracted with hot water. The carbonaceous residue is saturated with $Ba(OH)_2$ dried and finally the carbon burned off, the ash extracted with 25 per cent. HCl and the solutions united, bringing them to 100 cc. volume. Ten cc. of this extract is run onto 10 or 15 gms. of purified sand, $Ba(OH)_2$ in excess added and this then thoroughly dried. When dry render just acid with solution of 25 per cent. HCl, add 2 cc. of saturated solution of $H_2C_2O_4$ and 2 cc. of alcoholic solution of curcumin (1 gm. per liter). Dry this mass over a paraffin bath (maintained at 105° C.) by aspirating air over it, the air being drawn through "potash bulbs" containing $Ba(OH)_2$ as it has been found that perceptible amounts of H_3BO_3 are carried off in the vapors. Add 1 cc. of curcumin solution and dry again in the same manner. Treat the liquid from the potash bulbs in the same way, finally extract all the dried residues with alcohol or methylated spirit, and compare coloration with that obtained by treatment of known amounts of H_3BO_3 in a similar manner. NaOH or KOH or their salts in large amounts interfere with the formation of the coloring matter. Excessive amounts of water are also inimical.

BOOK REVIEWS.

Notes on Metallurgical Analysis. By N. W. LORD, Professor of Metallurgy and Mineralogy. New edition rewritten and greatly enlarged. A text-book for students in metallurgical chemistry. Price, $2.50, postage paid. Metallurgical laboratory, Ohio State University, Columbus, Ohio.

This work is a much enlarged edition of the book with the same title published in 1893. The ground covered is the analysis of limestone, iron ores, pig iron, steel, furnace and flue gases, slags, fire clays, copper in ores, zinc in ores, alloys of lead, antimony, etc., and water for boilers. Two hundred and eight pages are devoted to the methods for the analysis of substances connected with the metallurgy of iron and steel; seven pages to the rest of metallurgical analysis, so that the book can be considered only as applying to the metallurgy of iron and steel with a couple of methods for copper and one for zinc added.

From this standpoint the methods are well selected and cover all the analyses likely to be required by an "iron chemist." There is no claim for originality except in the notes to some of the determinations, particularly limestone. These were the best features of the original edition. The methods of analysis are taken largely from the *Journal of the American Chemical Society* and are very similar to those published in "Methods of Iron Analysis" used in the region around Pittsburgh, edited by F. C. Philips, but the repetition of that work is avoided and the methods are arranged so as to be more useful to students.

Many references are given and the book is to be recommended as a convenient and well-selected collection of the methods needed by those engaged in the metallurgy of iron and steel.

E. H. M.

Electricity as Applied to Mining. By ARNOLD LUPTON, M.I.C.E., M.I. Mech.E., M.I.E.E., late Professor of Mining in Yorkshire College, Mining Engineer and Colliery Manager; G. D. ASPINALL PARR, M.I.E.E., A.M.I.Mech.E., head of Electrical Engineering Dept., Yorkshire College, and HERBERT PERKIN, M.I.M.E., Cert. Colliery Mgr., and Lecturer in Mining, Yorkshire College. New York, D. Van Nostrand Co., 1903. 280 pp., 171 ills. Price, $3.50.

The present wide and successful employment of electric transmission of power for mine service has been brought about within but little more than twenty-five years. A striking commentary upon its comparatively recent and wonderfully rapid introduction into this field of work is to be found in the fact that in Callon's elaborate and still useful work on mining, which was completed and published soon after his death in 1875, there is no mention of electric-driven machinery of any kind, and only a

brief reference to the possibilities and advantages of electric blasting. Nor did the lighting of mines by electricity receive from him more than scant notice. In Callon's time the electric lamp consisted of three parts: a Bunsen cell, a Rhumkorff coil and a Geissler tube, and it is not surprising that he dismissed the subject with the remark that "the idea of illuminating a mine with the electric light should be relegated to the number of chimerical propositions which it is not worth while even to attempt to solve." Certainly the time had not yet come to apply to the uses of the miner the new agent for lighting and the transmission of power, the principles of which were then being demonstrated by the scientists, and which is now employed in a multitude of forms in all mining regions.

In the work under consideration, some 60 pages are devoted to an explanation of the general principles of electricity; its production by chemical means, with illustrated descriptions of well-known primary and secondary cells; a brief résumé of the theory of direct and alternating currents, and the construction of standard forms of generators, motors and transformers. Notwithstanding the necessity for condensation in a handbook of this character, these subjects are presented clearly and in sufficient detail for the needs of those for whom the work is particularly intended. It may be noted, however, that the references to the construction of continuous-current, gas-tight motors, for use in collieries containing firedamp, are hardly adequate, and could have been extended with advantage. A more detailed discussion would be acceptible, also, as to the unfavorable and trying conditions under which electric appliances are often called upon to operate underground, and the construction of motors, etc., especially adapted for such service.

The details given in Chapter III. of tests on several electric plants, working under varying conditions as to load, will be found useful; as also the application of steam turbines for the direct driving of generators (Chap. IV.). Next are taken up the distribution of electrical energy, the control of generators and motors, switchboards, lightning a resters and measuring instruments; all rather briefly presented.

Chapters VII. and VIII., dealing with electric cables and conductor l nes, and the design and establishment of central generating plants, are decidedly more satisfactory. They contain useful figures of cost of plant and operating expenses, together with an outline of the method of making calculations for high- and low-tension transmission to various distances, accompanied by a detailed summary, showing in tabular form the costs and percentages of loss. There are also very good descriptions of carrying the current down shafts and into the mine workings. Though the figures given apply chiefly to the conditions prevailing in Great Britain, they may be made of general application by altering them in conformity with the prices and wages of other regions.

The use of electricity for hoisting, pumping, drilling; coal-cutting, underground haulage, lighting and signalling, with notes on a few typical plants, are next considered. Here again the reader might desire a more detailed treatment of the subject, with a fuller citation and comparison of examples of recent installations. In view of the development of electric hoisting on a large scale, within the past few years, and the great size of some of the recently erected German plants, further data should certainly be given in addition to the notes on pp. 136 and 245.

In Chapter XIV. is presented a comparison of electric and other modes of transmitting power, *i. e.*, by steam, rope driving, compressed air, etc. The work closes with a chapter on the possible dangers of electrical transmission, particularly in collieries, containing a number of useful suggestions as to the arrangement of conductors underground to avoid fire, fuses and circuit-breakers, sparking, short-circuiting and detection of faults in the circuit.

Altogether, the book is fairly satisfactory. Such a hand-book is really needed by mining engineers, superintendents and students of mining, and by the amplification of some of the sections which are unnecessarily brief, a second edition may be materially improved.

R. P.

A Course in Botany and Pharmacognosy. By HENRY KRAEMER. New York, G. E. Stechert, 1902. 8vo, pp. 1–384, f. 1–128. Price, $3.50.

The author, Professor Henry Kraemer, was graduated from the School of Mines, receiving in 1895 the degree of Bachelor of Philosophy in Analytical and Applied Chemistry. The present volume represents the results of his experience as a teacher in botany and pharmacognosy during the past several years in the Philadelphia College of Pharmacy. As such it is deserving of careful consideration, for every presentation of a successful course of study in any subject is as valuable a contribution to science and as deserving of credit as original investigation. Work of this character is often apparently a thankless task but the fundamental importance of it as a preparation for the successful accomplishment of the world's work can not be overestimated.

An examination of this book reveals a carefully arranged and digested system of instruction and it is a matter for congratulation that such a work upon this subject has appeared. It would be difficult to imagine a subject of more vital importance to people in general than this relating to the training of druggists. It can hardly be questioned that the preparation of the pharmacist to-day is often superficial and that there is frequently a tendency on the part of the student to neglect this preparatory work. Commercial interests also too often lead to the substitution of inferior and cheaper drugs for those of higher grade or to the introduction of adulterants which though harmless in themselves nevertheless render medicines uncertain in action and so jeopardize life. A case in hand was recently revealed by the health board in this city in the almost universal adulteration of a drug. This mercenary and conscienceless bartering of human safety is less worthy of note than the fact that the dispensors of the drug were ignorant of the adulteration.

Professor Kraemer has prefaced his work with a short introduction to the study of botany, in which the fundamental structures and functions of the root, leaf, stem and flower are considered, together with a careful consideration of the forms and contents of the cell — a field in which the pharmacist is especially interested. This portion of the book comprises 100 pages and is supplemented with 128 excellent illustrations. While recognizing the difficulty that has to be met in presenting the subject of pharmacognosy to students totally ignorant of botany we can only regret that it is necessary to offer such an abridged course as is found in the first part of the book. While present entrance requirements endure and

so long as the universal desire to qualify for life work by the shortest possible course directs and shapes the curriculum, we must accept these introductions as the best that the conditions permit. This is not offered in a spirit of criticism of the book but of the conditions that compel the author to present only so much of botanical science as his experience has shown to be indispensable to fit the student for a study of drugs. The student should already be familiar with much of the information here presented and thus would he have more time for mastering the second portion of the work.

Part II. deals with Pharmacognosy. This comprises the really important portion of the book and will naturally attract the most attention. An introductory chapter treats of the collection, preservation, admixtures, valuations, etc., of drugs. The information here presented is especially important and timely since too often are seen gross carelessness and ignorance in these matters. In the following chapters are considered the Crude Vegetable Drugs, Powdered Vegetable Drugs, and Reagents. Under the first of these titles the seeds, underground organs, stems, flowers, fruits, leaves and exudations that are of medicinal value are considered. The powdered vegetable drugs are classified and considered according to their color and under reagents practical methods of treating and studying are given.

The treatment accorded this portion of the work marks a new and important departure from all other works dealing with pharmacognosy. Each subject as seeds, roots, flowers, powders, etc., is prefaced by a key for the identification of any specimen in hand. Following this scheme there is brought together under each organ or drug all the data relating to its appearance, occurrence, gathering, perservation, constitutents, adulterants, etc. Perhaps the most noteworthy portion of the book relates to the treatment of powdered drugs. The author has already attracted attention in this line of work, having received the Ebert and Maisch prize for his paper on the identification of powdered drugs, published in the *Proceedings of the American Pharmaceutial Association* in 1898. It will be noted that as here presented it has been substantially recast and elaborated and appears for the first time accompanied by a key and index.

This systematic description of drugs after the manner of the botanical systematist, appearing for the first time in a work of this kind, is one of the most important and valuable features of the book and is destined to have a marked influence upon future publications. The presentation of the subject is worthy of high commendation and will prove to be a decided advance over the plan of treatment given in pharmacopœias.

CARLTON C. CURTIS.

Plattner's Manual of Qualitative and Quantitative Analysis with the Blow-Pipe. Translated by HENRY B. CORNWALL, E.M., Ph.D, Professor of Applied Chemistry and Mineralogy in Princeton University. Assisted by JOHN H. CASWELL, A.M., from the Sixth German Edition by Professor FRIEDRICH KOLBECK, of the Mining Academy at Freiberg, Saxony. Eighth edition revised. New York, D. Van Nostrand Company. 8vo, cloth, 463 pages, illustrated. Price, net, $4.00.

No essential alterations have been made in this edition of Plattner s Manual. The blow-pipe behavior of a number of new minerals has been

added, the chemical notation and names of species have been modernized. The size of the book has been somewhat diminished by the omission of some sections, notably the tabulated tests of the different oxides with borax, salt of phosphorus, soda, etc., and by the use occasionally of smaller type.

The manual includes all the corrections made in the sixth and last German Edition, and contains complete indexes and a revised table of atomic weights.

A. J. M.

JUST PUBLISHED

8vo, Cloth, 287 Pages, Illustrated. Price, $3.50 *net*
Postage 25 cents

Conductors for Electrical Distribution;

Their Materials, and Manufacture, the Calculation of Circuits, Pole Line Construction, Underground Work, and Other Uses

By F. A. C. PERRINE, A.M., D.Sc.

Formerly Professor of Electrical Engineering, Leland Stanford, Jr., University; Member American Institute Electrical Engineers

---

8vo, Cloth, Illustrated, 122 pp. Price, $1.25 *net*
Postage 10 cents

Experiments on the Flexure of Beams

Resulting in the Discovery of New Laws of Failure by Buckling

By ALBERT E. GUY

Reprinted from the "AMERICAN MACHINIST"

8vo, Cloth, 1100 Illustrations, 460 pp. Price, $3.00

THIRD ENGLISH EDITION REVISED

Handbook on the Steam Engine

With Especial Reference to Small and Medium-Sized Engines

For the Use of Engine Makers, Mechanical Draughtsmen, Engineering Students, and Users of Steam Power

By HERMAN HAEDER, C.E.

Duisburg-on-the-Rhine

Translated from the German, with Considerable Additions and Alterations

By H. H. P. POWLES

Assoc. Memb. Inst. C.E., M.I.M.E.

D. VAN NOSTRAND COMPANY

Publishers and Booksellers

23 MURRAY and 27 WARREN STS., NEW YORK

Copies Sent Prepaid on Receipt of Price

Woodbridge School,

FORMERLY

School of Mines Preparatory School.

---

417 Madison Avenue,

Between 48th and 49th Streets, NEW YORK CITY

Twenty-second Year Begins October 1st, 1903.

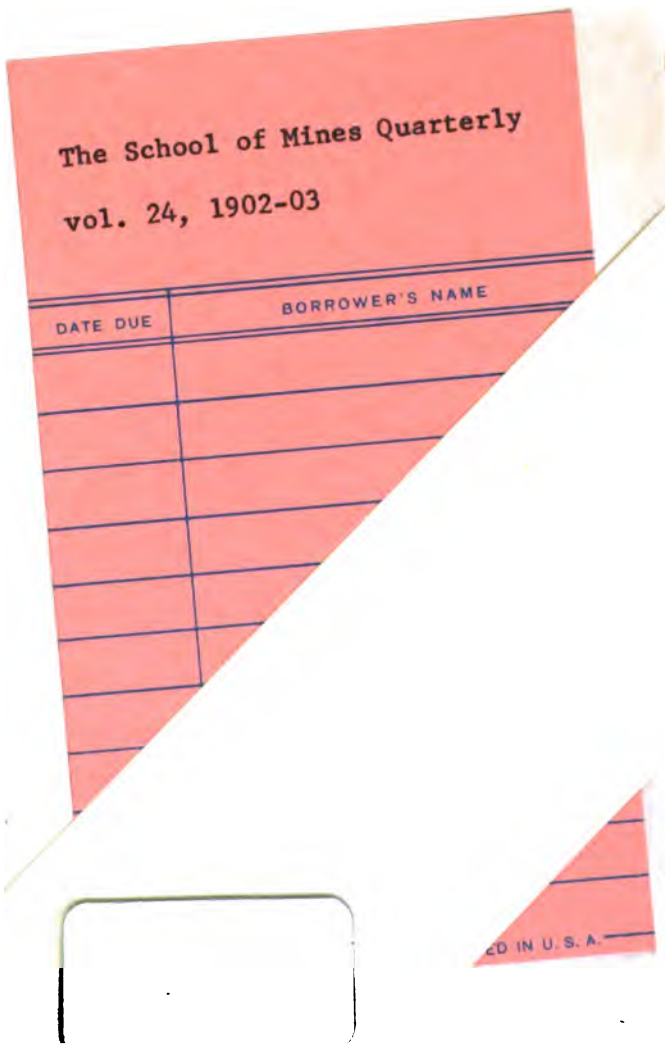
THE school is well equipped with physical and chemical laboratories, in which the students are required to perform a complete set of experiments illustrative of their recitations in physics and general chemistry. A special laboratory is devoted to qualitative chemical analysis for advanced students.

Five hundred Students of Columbia School of Mines have been instructed in the Woodbridge School. Also a large number have been prepared for Massachusetts Institute of Technology, Stevens Institute, Sheffield Scientific School, Lawrence Scientific School, Troy Polytechnic Institute, Cornell University, and the Classical, Medical, and Law Departments of Harvard, Yale, Columbia and Princeton.

A summer school for students who have failed in June begins August 13th and coaches men for the Fall examinations. All classes are limited to five. College men are coached in Freshman and Sophomore Mathematics and Quantitative Analysis.

An advanced course for older students prepares them to enter the second-year class Last June one of our students received his degree in Electrical Engineering in three years.

SERIAL


The School of Mines Quarterly
vol. 24, 1902-03
DATE DUE
BORROWER'S NAME
ED IN U. S. A.